The effect of stage of growth and implant exposure on performance and carcass composition in steers[1]

K. W. Bruns[2], R. H. Pritchard, and D. L. Boggs

Department of Animal and Range Sciences, South Dakota State University, Brookings 57007

ABSTRACT: Angus and Angus × Limousin cross steers (n = 182; initial BW = 309 ± 27.8 kg) were used to evaluate the influence of an estradiol–trenbolone acetate implant (containing 24 mg of estradiol and 125 mg of trenbolone acetate) on production efficiency and carcass traits when administered at specific stages of growth. Treatments were 1) control, no implant (NI); 2) early implant (EI) on d 1 (BW = 309 kg); or 3) delayed implant (DI) on d 57 (BW = 385 kg). Comparisons were also made between the NI and implanted treatments (I; EI + DI). Steers were procured at weaning and were backgrounded (47 d) before the initiation of the experiment. Initial predicted carcass composition was 14.9% protein, 13.3% fat, 54.6% moisture, and 17.2% bone. Days on feed were constant across treatment. After 56 d, ADG and G:F were improved ($P < 0.01$) by implants, NI vs. EI (1.68 vs. 1.90 kg and 0.227 vs. 0.257). At d 57, predicted carcass composition did not differ among treatments. From 57 to 112 d, DI caused higher ADG than NI or EI (NI = 1.65, EI = 1.57, and DI = 1.78 kg; $P < 0.05$) and higher G:F (NI = 0.155, EI = 0.150, and DI = 0.173; $P < 0.01$). Cumulative ADG and G:F were improved by implants (1.65 vs. 1.73 kg; $P < 0.05$) and (0.175 vs. 0.186; $P < 0.01$) for NI vs. I, respectively, with no differences between treatments that involved implants. Cumulative DMI was similar for all treatments. Implanting increased dressing percentage (63.5 vs. 64.1%; $P < 0.05$) and increased ($P < 0.01$) hot carcass weight (341 vs. 353 kg) and LM area (76.5 vs. 81.4 cm^2) for NI vs. I, respectively. Rib fat and kidney, pelvic, and heart fat were not affected by treatment, and treatment had no effect on the whole carcass proportions of fat, protein, or water. Implants advanced maturity scores (NI = A^{51} vs. EI + DI = A^{59}; $P < 0.01$). Marbling scores were decreased ($P < 0.05$) by EI but not by DI (NI = $Small^{65}$, EI = $Small^{20}$, DI = $Small^{36}$). The percentage of i.m. fat content of the LM was decreased ($P < 0.10$) by EI and was not affected by DI (NI = 5.1, EI = 4.0, DI = 4.8%). Treatment affected ($P < 0.10$) the proportion of carcasses with marbling scores greater than $Modest^0$ (NI = 23.6, EI = 7.8, DI = 22.6%). The results of this study suggest that growth of i.m. fat is sensitive to anabolic growth promotants administered during early periods of growth.

Key Words: Beef, Body Composition, Implants, Estradiol, Trenbolone Acetate

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Introduction

Beef producers have used growth-promoting implants for the past 40 yr to improve growth rates by 30% and feed efficiency by 15% (Preston, 1999). Implanting can improve carcass leanness by up to 8% compared with nonimplanted controls at the same BW. In 1991, the option of using a single implant that contained both an estrogen (estradiol) and an androgen (trenbolone acetate, **TBA**) was made available to beef producers. The combination of estradiol and TBA increased ADG and feed efficiency more than either substance alone (Preston, 1999). Research has shown that administration of a combination implant too close to slaughter can decrease marbling scores (Kerth et al., 1996). Pritchard (2000) suggested that the decrease in quality grade might result from administering an improper implant strategy. Using implants that differed in their level of potency, Pritchard (2000) reported that carcasses developed marbling scores similar to nonimplanted contemporaries if a lower-potency implant was administered early in the finishing phase. The disparity between experimental outcomes among studies may lie in the timing as well as the potency of the implant. Understanding how implants affect marbling development would aid in the selection of more appropriate implant strategies. This study was conducted to quantify the growth of intramuscular fat relative to changes in body composition in steers fed high-energy diets and

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[2]Correspondence: ASC 217 Box 2170 (phone: 605-688-5452; fax: 605-688-6170; e-mail: kelly_bruns@sdstate.edu).

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implanted at two different points in the finishing phase growth curve.

Materials and Methods

Animals

Angus and Angus × Limousin cross spring-born steers (n = 186) were weaned and transported 545 km to the South Dakota State University (**SDSU**) Nutrition Unit, where they were individually tagged and processed in early November. Before initiating the study, steers were backgrounded for 47 d at a targeted gain of 1 kg/d. Steers were ranked by weight and four outliers were removed. Fifteen steers that were closest to the mean weight of the group were selected and randomly assigned to one of three serial slaughter treatments. Steers selected for serial slaughter were fed in pens by treatment. To measure production variables, the remaining 167 steers were randomly assigned to one of three treatments with seven replicates per treatment: 1) control, no implant (**NI**); 2) early implant (**EI**) on d 1 (BW = 309 kg); or 3) delayed implant (**DI**) on d 57 (BW = 385 kg). The implant that was administered for implanted treatments was an estradiol–TBA implant containing 24 mg of estradiol and 120 mg of TBA (Revalor-S, Intervet, Millsboro, DE). The allotment system caused a similar distribution of BW in each pen. Steers were fed in paved outdoor pens measuring 7.6 × 7.6 m deep, with a 7.6-m fence-line feed bunk. Each pen contained seven or eight steers. Steers were fed once daily in the afternoon and had continual access to water. Steers were brought up to ad libitum intakes within 14 d. The finishing diet comprised (DM basis) 40% whole shelled corn, 40% high-moisture corn, 10% ground grass hay, and 10% supplement, which contained (on a DM basis) 12.9% ± 0.09 CP, 6.1% ± 0.12 ADF, 13.7% ± 0.36 NDF, and 3.2% ± 0.08 ash, and was 74.9% ± 0.72 DM. The estimated final dietary energy density was 2.06 Mcal/kg of NE_m and 1.36 Mcal/kg of NE_g. Cattle were weighed on trial on December 21, 2000, at which time implants were administered to EI steers. Steers (n = 5) assigned to the initial slaughter group were transported to the SDSU Meat Lab and processed.

Three calves were removed from the study with their BW contribution to the pen mean deleted from the onset of the experiment. The South Dakota State University Animal Care and Use Committee approved the care, handling, and sampling of animals used in this study.

Steers were weighed every 28 d to monitor weight gain and to schedule appropriate implant and slaughter dates. Steers averaged 385 kg on d 56. The following day (d 57), the DI treatment (Revalor-S, Intervet) was administered. On d 58, steers assigned to serial slaughter from the EI treatment (n = 5) and nonimplanted (n = 5) were transported to the SDSU Meat Lab for slaughter. When the average of all steers visually reached 1.00 cm of rib fat thickness, 30 steers (n = 10 from each treatment) were selected from near the mean BW of each treatment for slaughter over a 10-d period at the SDSU Meat Lab for compositional analysis. This began after 140 d on feed. Production data were calculated through 140 d to maintain the integrity of the experimental units (pens). The remaining steers (n = 134) were transported 75 km to a commercial packing plant. Carcass data collected included hot carcass weight (**HCW**), LM area, s.c. rib fat thickness (**RF**), and percentage of kidney, pelvic, and heart fat (**KPH**) depots (USDA, 1996). Estimates of bone maturity and marbling score (to the nearest tenth) were recorded by trained university personnel or an official USDA meat grader. For steers slaughtered at the South Dakota State University Meat Lab (n = 30) the KPH depot was removed by physical separation from each side of the chilled carcass and weighed to determine the actual percentage of KPH relative to carcass weight.

Carcass Composition

Following carcass data collection, the 9th-10th-11th rib section was removed from the right side of each carcass as outlined by Hankins and Howe (1946) on the steers (n = 30) slaughtered at the SDSU Meat Laboratory. Soft tissue was separated from bone and weights were obtained on each. The soft tissue was mixed and homogenized in a bowl chopper. Three samples weighing 100 g each were obtained and stored in polyethylene bags at –20°C. Chemical analysis of the soft tissue was conducted to determine the water, ether extract (fat), and N contents of the 9th-10th-11th rib section samples. Two 50-g samples were lyophilized to a constant weight (48 h). Water was calculated as the difference between the wet sample and lyophilized sample weight. The lyophilized samples were then combined and immersed in liquid N and subsequently powdered with a Waring commercial blender (Waring Products Division, New Hartford, CT). Samples (2 g) were wrapped in ashless filter paper and extracted with petroleum ether in a side arm Soxhlet (AOAC, 1990) to a constant weight (60 h) for ether extraction of lipid followed by drying at 60°C for 12 h. Crude fat was calculated as the difference between lyophilized and extracted sample weight. Crude protein was measured on extracted samples (1 to 1.5 g) by the macro-Kjeldahl method (AOAC, 1990). Ash content was determined on 1-g lyophilized samples held at 650°C for 12 h. Hankins and Howe (1946) equations for steers were used to predict composition of the carcass soft tissue from chemical composition of soft tissue from the 9th-10th-11th rib section and to predict the percentage of carcass fat, protein, moisture, and ash. Equations are as follows: carcass fat = 3.49 + 0.74 (9th-10th-11th rib fat content); carcass protein = 61.9 + 0.65 (9th-10th-11th fat protein content); (Hankins and Howe, 1946). Whole carcass values were calculated by equations outlined by Hankins and Howe (1946) and used for determination of fractional growth rates. Empty body weight (**EBW**) was

Table 1. Effect of implant (Revalor-S) on feedlot performance

	Treatment				
Variable	NI[a]	Early implant[b]	Delayed implant[c]	SEM	*P*-value[d]
No. of pens	7	7	7		
Initial BW, kg	308	309	309	0.99	0.805
BW, kg					
d 56	403[e]	415[f]	404[e]	213	0.002
d 112	495[e]	504[f]	504[f]	2.8	0.066
d 140	539[e]	550[ef]	551[f]	3.9	0.089
ADG, kg					
d 0 to 56	1.68[e]	1.90[f]	1.70[e]	0.041	0.004
d 57 to 112	1.65[e]	1.57[e]	1.78[f]	0.032	0.002
d 113 to 140	1.58	1.65	1.70	0.056	0.365
d 0 to 140	1.65[e]	1.72[ef]	1.73[f]	0.026	0.087
DMI, kg					
d 0 to 56	7.39	7.41	7.41	0.012	0.715
d 57 to 112	10.61	10.42	10.32	0.103	0.174
d 113 to 140	11.16	10.78	10.83	0.158	0.218
d 0 to 140	9.64	9.47	9.42	0.070	0.203
G:F					
d 0 to 56	0.227[e]	0.257[f]	0.229[e]	0.005	0.008
d 57 to 112	0.155[e]	0.150[e]	0.173[f]	0.003	0.001
d 113 to 140	0.141[e]	0.153[ef]	0.157[f]	0.005	0.085
d 0 to 140	0.175[e]	0.185[f]	0.187[f]	0.002	0.005

[a]NI = no implant; control.
[b]Early implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 1, BW = 309 kg.
[c]Delayed implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 56, BW = 385 kg.
[d]Overall *F*-test.
[e,f]Means within rows that do not have a common superscript differ, $P < 0.05$.

calculated by the following equation of Old and Garrett (1987), where EBW = ([1.316 × HCW] + 32.237).

Longissimus Sample

On the carcasses (n = 30) that were slaughtered for body composition study, a 1-cm slice of the LM was removed from the posterior portion of the 12th-rib section from the right side of the carcass. All exterior fat and epimysial connective tissue was removed. The sample was then cut into 1 cm × 1 cm cubes and stored in plastic bags (Whirlpack, Nasco, Fort Atkinson, WI) at –20°C. Samples were homogenized in liquid N as outlined previously. Ether extraction of the LM samples was performed in triplicate to quantify percentage of intramuscular fat (**IMF**) content of the LM at the 12th rib as outlined previously with the 9th-10th-11th rib sample.

Fractional Growth

Fractional growth rate (**FGR**) was calculated as outlined by McCarthy et al. (1983) as the rate of carcass protein and fat gain divided by the total carcass protein or fat of the animal at the point of reference (d 0, 56, or 150). Growth rate is reported as a percentage increase in mass of growth per day. The equation to calculate FGR is as follows: $FGR = ([P_1 - P_0]/T)/([P_1 + P_0]/2)$, where P_1 is the later measure of carcass tissue, P_0 is the earlier measure of carcass tissue, and T is the number of days between the two measurements.

Statistical Analyses

All performance variables were evaluated using GLM procedure of SAS (SAS Inst., Inc., Cary, NC) in a statistical model that included treatment in a one-way treatment design. The experimental unit in these analyses was pen. Fisher's LSD was used to separate treatment means. Analysis of carcass data was conducted using a complete random design in a model that included the main effect, implant treatment. Carcass traits were regressed against empty BW and partitioned into comparisons for linear, quadratic, and cubic relationships based on contrasts for the model (Steel and Torrie, 1960). Regression equations were developed to quantify the change in carcass characteristics and composition throughout the feeding phase with $P < 0.05$ considered significant and $P < 0.10$ tending to be significant.

Results and Discussion

Feedlot Performance

Feedlot performance data are summarized in Table 1. Implanting increased BW and ADG, which are similar to responses reported by others (Duckett et al., 1997). The estradiol–TBA implant (containing 24 mg

of estradiol and 120 mg of trenbolone acetate) administered on d 0 (EI) increased ($P = 0.002$) BW by 3% and increased ($P = 0.004$) ADG 11% to d 56. During the period from d 57 to 112, implanted steers had 2% greater ($P = 0.05$) BW than NI. The responses reported here are lower than previously reported by Preston and Rains (1993) and Pritchard (2000), who reported a 20% increase in ADG, as well as by Johnson et al. (1996), who observed an 18% increase in ADG over 140 d. The authors (Preston and Rains, 1993; Johnson et al., 1996; Pritchard, 2000) reported that implanted steers maintained greater gains throughout the experiment than controls. In the present study, EI steers implanted had increased ADG up to d 56, but d 57 to d 112 and cumulative ADG (d 140) did not differ from controls or DI.

The lower than expected ADG response in this trial may be because implants did not stimulate ($P > 0.10$) DMI for the first 56 d. Additionally, cumulative DMI did not differ ($P > 0.10$) among treatments (Table 1). These results are similar to those reported by Johnson et al. (1996) but in contrast to those of Bartle et al. (1992) and Pritchard (2000), who reported that estradiol–TBA implants stimulated DMI. In the present study the failure of the implant treatment to elicit a DMI response may have been caused by the high intake occurring during cold, winter weather.

Gain efficiency was improved ($P = 0.003$) 13% for EI vs. NI the first 56-d period. At the conclusion of the trial, steers receiving an implant (EI or DI) had 10.5% improvement ($P = 0.002$) in feed efficiency over controls. This response is similar to previously reported results of 13% (Johnson et al., 1996) and 14% (Pritchard, 2000). However, EI did not maintain the advantage in G:F over controls from d 56 to d 112, whereas others (Johnson et al., 1996; Pritchard, 2000) have reported an advantage throughout the duration of the trial (140 d for Johnson et al., 1996; 145 d for Pritchard, 2000).

Carcass Characteristics and Composition

Carcass measurements and carcass composition for the initial slaughter group are shown in Table 2. Serial slaughter at d 56 and the final slaughter on d 150 are presented in Table 3. During the first 56 d, HCW increased ($P = 0.010$) for EI vs. NI, with no differences observed for other carcass traits. Implanting increased ($P = 0.010$) carcass weights by improved ($P = 0.011$) dressing percent, as well as by increasing BW at final slaughter. Eversole et al. (1989) found no difference in dressing percent for steers receiving one estradiol–TBA implant, but reported an increase in dressing percent for steers that were reimplanted with estradiol–TBA. Others (Perry et al., 1991; Pritchard, 2000) have reported increases in HCW with no difference in dressing percent.

No differences were found among treatments for s.c. RF at the 12th rib, which is similar to previous results (Eversole et al., 1989; Perry et al., 1991; Bartle et al., 1992; Pritchard, 2000). Implanting increased ($P < 0.001$) LM area on d 150, which is similar to reports by Eversole et al. (1989), Bartle et al. (1992), and Pritchard (2000). Longissimus muscle area measurements for EI steers at initial (d 0) and on d-56 slaughter dates were not different from controls. These findings are similar to results reported by Johnson et al. (1996), who noted no difference in LM area 40 d after implanting with estradiol–TBA acetate. No difference was observed for KPH fat in steers slaughtered at d 56 or d 150. Similarly, Milton et al. (2000) reported no difference for KPH fat in steers administered an estradiol–TBA implant (28 mg/200 mg) on d 0, 35, or 70 compared with nonimplanted controls. Others (Bartle et al., 1992; Johnson et al., 1996) reported that implanted steers had less KPH than nonimplanted steers. Yield grade did not differ among treatments at d 56, which is similar to serial slaughter findings of Johnson et al. (1996), who reported no difference in yield grade at 40, 115, and 143 d after implanting. However, at final slaughter DI had lower ($P = 0.038$) yield grade than NI, which is in contrast to the findings of Eversole et al. (1989) and Bartle et al. (1992), who reported no difference in yield grade between implanted and nonimplanted steers.

Early implant treatment decreased ($P = 0.021$) marbling scores compared with controls, with no difference ($P = 0.36$) between NI and DI at final slaughter. Likewise, EI caused a lower ($P = 0.070$) percentage of carcasses with marbling scores of greater than or equal to Modest^{00} (Table 4). Morgan (1997) stated that TBA-containing implants produced approximately 25% fewer carcasses grading Choice or higher, whereas Kerth et al. (1996) reported that a combined estradiol–TBA implant decreased marbling scores one full marbling score compared with nonimplanted controls. In the present study, we found that EI on d 0 decreased ($P = 0.006$) marbling scores compared with controls, whereas DI was similar to controls. Both Eversole et

Table 2. Initial carcass traits and composition of steers (n = 5)

Item	Mean ± SE
Carcass measurements	
BW, kg	294 ± 3.0
Hot carcass wt, kg	172 ± 5.8
Dressing percent[a]	60.9 ± 0.51
Rib fat, cm	0.21 ± 0.023
LM area, cm^2	61.2 ± 2.43
Kidney, pelvic, and heart fat, %	1.6 ± 0.09
Maturity[b]	132 ± 2.0
Marbling[c]	328 ± 8.0
Intramuscular fat content, %	1.46 ± 0.2
Predicted carcass composition[d]	
Protein, %	14.94 ± 0.200
Fat, %	13.25 ± 1.165
Moisture, %	54.61 ± 0.935
Bone, %	17.20 ± 0.197

[a]Dressing percent = [hot carcass weight/(BW × 0.96) × 100].
[b]100 = A^0 maturity.
[c]300 = Traces^{00}; 400 = Slight^{00}; 500 = Small^{00}.
[d]Predicted values derived from Hankins and Howe (1946).

Table 3. Effect of implant (Revalor-S) on carcass characteristics[a]

	Slaughter groups[b]								
	d 56 slaughter				Final slaughter				
Variable	NI[c]	EI[d]	SEM	*P*-value[f]	NI[c]	EI[d]	DI[e]	SEM	*P*-value[f]
No.	5	5	—	—	55	51	53	—	—
HCW, kg[g]	227[v]	243[w]	3.2	0.010	341[x]	352[y]	354[y]	3.9	0.034
DP[h]	58.9	60.8	0.74	0.109	63.5[x]	64.1[y]	64.3[y]	0.24	0.038
Rib fat, cm	0.48	0.70	0.23	0.515	1.34	1.29	1.24	0.051	0.380
LM area, cm^2	66.8	69.2	1.38	0.269	76.4[v]	80.4[w]	82.3[w]	0.96	0.001
Kidney, pelvic, heart fat, %	2.1	2.2	0.14	0.766	2.2	2.2	2.1	0.11	0.969
USDA yield grade	2.0	2.2	0.20	0.417	3.3[x]	3.2[xy]	3.0[y]	0.08	0.038
Maturity[i]	140	138	1.4	0.347	151[x]	161[y]	156[z]	1.8	0.002
Marbling[j]	448	396	22.0	0.134	565[x]	520[y]	536[xy]	11.3	0.021

[a]Least squares means.
[b]Statistical comparisons made within slaughter group.
[c]NI = no implant; control.
[d]Early implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 1, BW = 309 kg.
[e]Delayed implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 56, BW = 385 kg.
[f]Overall *F*-test
[g]HCW = hot carcass weight.
[h]Dressing percent = hot carcass weight/(BW × 0.96).
[i]100 = A^{00} skeletal maturity.
[j]500 = $Small^{00}$; 600 = $modest^{00}$.
[v,w]Means within rows that do not have a common superscript differ, $P < 0.01$.
[x,y,z]Means within rows that do not have a common superscript differ, $P < 0.05$.

al. (1989) and Bartle et al. (1992) reported decreased marbling scores with administration of an estradiol–TBA implant on d 0 compared with controls. An objective measurement of IMF content was conducted by quantifying the percentage of IMF content of the longissimus dorsi at the 12th rib (n = 30). No differences for IMF were detected among treatments at 56 d or 150 d; however at 150 d, EI steers had a percentage of IMF that was 21% lower than controls (5.08 vs. 4.03).

Initial carcass composition was derived from five steers selected to be a representative sample of steers in the experiment (Table 2). Whole carcass composition of steers serially slaughtered at d 56 and final slaughter are presented in Table 5. Implanting with an estradiol–TBA implant at d 0 or 56 had no effect on percentage of whole carcass protein, fat, moisture, or bone. Likewise, no differences among treatments were detected when proportions of protein and fat were evaluated on an EBW basis. These results are similar to results reported by Johnson et al. (1996), who found no difference in the percentage of carcass components throughout serial slaughters at d 40, 115, and 143.

Table 4. Effect of implant (Revalor-S) on quality grade distribution[a]

Quality grade	NI[b] n = 55	EI[c] n = 51	DI[d] n = 53
	%		
Premium Choice[e]	23.6[f]	7.8[g]	22.6[f]
Low Choice	45.5	52.9	39.6
Select	30.9	37.3	37.8
Standard	0.0	2.0	0.0

[a]χ^2 analysis.
[b]NI = no implant; control.
[c]Early implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 1, BW = 309 kg.
[d]Delayed implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 56, BW = 385 kg.
[e]$Modest^{00}$ and higher.
[f,g]Means within rows that do not have a common superscript differ, $P = 0.070$.

Fractional growth rates for protein, fat, and percentage of IMF are presented in Table 6. During the initial 56 d, steers receiving an implant on d 0 (EI) had greater FGR for protein compared with NI (NI 0.41 vs. EI 0.53; $P = 0.021$), with no difference in the FGR of carcass fat. Steers receiving an implant on d 57 had greater ($P = 0.012$) rates of protein accretion from d 57 to d 150 compared with steers receiving an implant on d 0. Fractional accretion rate of percentage of IMF during the first 56 d did not differ between NI and EI, but EI numerically reduced FGR by 43% compared with NI. Cumulative FGR for protein and fat were not different among treatments, but the FGR of IMF tended to be lower ($P = 0.06$) for EI compared with NI.

Empty body weight composition data in serially slaughtered steers are presented in Table 7. Implanting on d 0 increased EBW ($P = 0.01$) the first 56 d on feed compared with NI. Likewise, EBW tended to increase ($P = 0.06$) for cattle receiving an implant (EI or DI) compared with NI at the conclusion of the study, with no difference in the percentage of protein or fat between treatments. Regression equations (Table 8) were developed by regressing kilograms of empty body fat (**EBF**),

Table 5. Effect of implant (Revalor-S) on predicted whole carcass composition of serially slaughtered group[a]

	Slaughter groups[b]								
	d 56 slaughter				Final slaughter				
Variable	NI[c]	EI[d]	SEM	*P*-value[e]	NI[c]	EI[d]	DI[f]	SEM	*P*-value[e]
No.	5	5			10	10	10		
HCW, kg[g]	227[w]	243[x]	3.2	0.010	341[y]	349[z]	348[yz]	2.9	0.095
Protein, %[h]	14.2	14.3	0.22	0.887	12.6	12.7	12.6	0.18	0.980
Fat, %[h]	19.1	17.6	0.76	0.196	28.8	28.4	28.1	0.93	0.874
Moisture, %[h]	50.3	51.8	0.63	0.116	44.8	45.6	44.9	0.68	0.652
Bone, %[h]	16.4	16.3	0.45	0.885	13.8[wx]	13.4[w]	14.4[x]	0.24	0.007
IMF content, %[i]	2.33	1.96	0.29	0.394	5.08[y]	4.03[z]	4.85[z]	0.39	0.161

[a]Least squares means.
[b]Statistical comparisons made within slaughter group.
[c]NI = no implant; control.
[d]Early implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 1, BW = 309 kg.
[e]Overall *F*-test.
[f]Delayed implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 56, BW = 385 kg.
[g]HCW, kg = hot carcass weight.
[h]Predicted values derived from Hankins and Howe (1946).
[i]IMF content = percentage of i. m. fat content of longissimus dorsi.
[w,x]Means within rows that do not have a common superscript differ, $P < 0.05$.
[y,z]Means within rows that do not have a common superscript differ, $P < 0.10$.

percentage of IMF, and marbling against EBW and were found to be linear. Steers receiving EI had lower ($P = 0.031$) rates of development of percentage of IMF compared with NI but were not different ($P = 0.111$) from DI (Figure 1).

To quantify differences in EBW at constant EBF (28%), IMF content (4.0%), and marbling score (Small^0), regression equations were developed for EBF, IMF, and marbling score as independent variables, with EBW as the dependent variable (Table 8). Empty body weights at a constant EBF, IMF, and marbling score are presented in Table 9. At 28% EBF, steers receiving an implant (EI or DI) were 5.7% heavier on average than controls. Steers implanted on d 0 (EI) had 15% greater EBW at constant IMF content of 4% than NI. Likewise EI had 7.3% greater EBW than NI at a marbling score of Small^0.

Equations published by NRC (1996) nutrient requirements of beef cattle adjust cattle so they are equivalent in body composition to the steers in the

Table 6. Effect of implant (Revalor-S) on fractional accretion rate of carcass tissue

Variable	NI[a]	EI[b]	DI[c]	SEM	*P*-value[d]
d 0 to 56 (n = 10)					
Protein	0.41[w]	0.53[x]		0.029	0.021
Fat	0.85	0.81		0.089	0.743
Intramuscular fat	0.76	0.43		0.235	0.358
d 57 to 150 (n = 30)					
Protein	0.30[wx]	0.26[w]	0.32[x]	0.017	0.037
Fat	0.82	0.84	0.82	0.031	0.798
Intramuscular fat	0.76	0.70	0.70	0.082	0.793
Cumulative (n = 30)[e]					
Protein	0.34	0.35	0.35	0.010	0.442
Fat	0.76	0.77	0.76	0.015	0.965
Intramuscular fat	0.73[y]	0.60[z]	0.69[yz]	0.044	0.142

[a]NI = no implant; control.
[b]Early implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 1, BW = 309 kg.
[c]Delayed implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 56, BW = 385 kg.
[d]Overall *F*-test.
[e]Average days on feed = 150.
[w,x]Means within rows that do not have a common superscript differ, $P < 0.05$.
[y,z]Means within rows that do not have a common superscript differ, $P < 0.10$.

Table 7. Effect of implant on predicted empty body composition[a]

	Slaughter groups[b]								
	d 56 slaughter				Final slaughter[c]				
Item	NI[d]	EI[e]	SEM	*P*-value[f]	NI[d]	EI[e]	DI[g]	SEM	*P*-value[f]
No.	5	5	—	—	10	10	10	—	—
Empty body wt, kg	332[h]	351[i]	4.1	0.010	480[j]	491[k]	491[k]	3.8	0.095
Empty body fat, %	17.0	15.6	0.64	0.196	26.0	25.6	25.4	0.86	0.874
Empty body protein, %	11.8	11.8	0.14	0.867	10.5	10.6	10.5	0.14	0.980
Empty body fat, kg	56.5	55.0	2.86	0.724	124.9	125.8	124.4	4.43	0.972
Empty body protein, kg	39.0[j]	41.5[k]	0.62	0.023	50.5	51.8	51.7	0.79	0.445

[a]Least squares means.
[b]Statistical comparisons made within slaughter group.
[c]Average days on feed = 150.
[d]NI = no implant; control.
[e]Early implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 1, BW = 309 kg.
[f]Delayed implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 56, BW = 385 kg.
[g]Overall *F*-test.
[h,i]Means within rows that do not have a common superscript differ, $P < 0.01$.
[j,k]Means within rows that do not have a common superscript differ, $P < 0.10$.

Garrett (1980) database. In the equations (NRC, 1996), the standard reference weight at which cattle reach an expected final body fat was determined by averaging the percentage of body fat of cattle in studies where body composition was measured and many different body types and sizes were represented (Harpster, 1978; Danner et al., 1980; Lomas et al., 1982; Woody et al., 1983) and the reference points are reported as 27.8% EBF at a small degree of marbling, with an EBW of 478 kg. In our study, control steers reached 28% body fat at 546 kg, whereas EI and DI reached 28% body fat at 579 and 597 kg, respectively (Table 9). Cattle in this study reached marbling scores of Small^0 at a lower percentage of body fat and had lower EBW at Small^0 marbling than those summarized by Fox et al. (1992) and Tylutki et al. (1994). It has been well documented that growth-promoting implants increase frame size (Loy et al., 1988; Perry et al., 1991; Fox et al., 1992). Implanted steers in our study reached 28% EBF at EBW that were 33 and 51 kg greater than controls for EI and DI, respectively. Perry et al. (1991) reported that steers implanted with estradiol–TBA, when compared with nonimplanted steers, reached a Small degree of marbling at live weights that were from 25 to 45 kg heavier than controls. In our study, NI and DI steers reached Small^0

Table 8. Regression equations describing the linear relationship between empty body weight (x) and carcass components (y) in steers implanted with Revalor-S[a]

Variable and treatment	Intercept	Linear component	r^2	*P*-value	SE
Empty body fat, kg[b]					
Not implanted[c]	–84.09970	0.433646	0.958	0.001	0.0214
Early implant[d]	–87.05683	0.430080	0.959	0.001	0.0003
Delayed implant[e]	–76.242307	0.407297	0.934	0.001	0.0255
Intramuscular fat content, %					
Not implanted[c]	–3.02809	0.016797	0.786	0.001	0.0021
Early implant[d]	–1.804642	0.011743	0.714	0.001	0.0018
Delayed implant[e]	–2.471052	0.014870	0.672	0.001	0.0025
Marbling					
Not implanted[c]	163.94213	0.73912	0.758	0.001	0.0985
Early implant[d]	133.67879	0.74567	0.743	0.001	0.1033
Delayed implant[e]	155.95645	0.07755	0.643	0.001	0.1348

[a]n = 5 steers at initial slaughter; 10 steers at 56 d slaughter; 30 steers at final slaughter.
[b]Dependent variable empty body weight = (1.316 × hot carcass weight) + 32.287; Old and Garrett (1987).
[c]Not implanted = control.
[d]Early implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 1, BW = 309 kg.
[e]Delayed implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 56, BW = 385 kg.

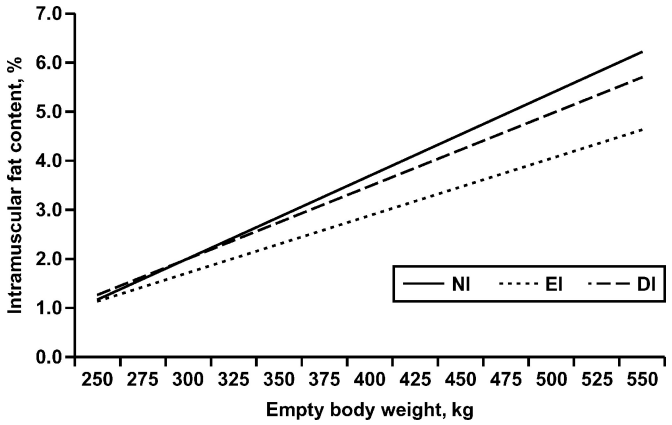

Figure 1. Effect of implant on rate of development of intramuscular fat content. NI = nonimplanted control; EI = early implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 1, BW = 309 kg; DI = delayed implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 56, BW = 386 kg; n = 45. NI differed from EI, $P < 0.05$.

at similar weights, whereas EI increased the live weight at which steers reached Small^0 by 36 kg compared with controls (Table 9).

Implications

Results of this study showed that a combined implant of estradiol–trenbolone acetate could affect carcass traits and the growth rate of carcass protein and fat depending on the point of administration in the feeding phase of production. Steers receiving a delayed implant can reach Small amounts of marbling at empty body weights similar to controls, whereas attaining greater carcass weights at 28% empty body fat. These results suggest that using a combined estradiol–trenbolone acetate implant early in the finishing phase could have adverse effects on the development of marbling.

Table 9. Effect of implant (Revalor-S) on empty body weight at constant empty body fat and percent intramuscular fat content[a]

	Empty body weight, kg[b]		
Variable	NI[c]	EI[d]	DI[e]
28% empty body fat[f]	546	579	597
4% intramuscular fat	420	495	435
Marbling score – Small^{00}	455	491	448

[a]Values determined by regression analysis.
[b]Empty body weight = (1.316 × hot carcass weight) + 32.287; Old and Garrett (1987).
[c]NI = control.
[d]Early implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 1, BW = 309 kg.
[e]Delayed implant = combined estradiol–trenbolone acetate containing 24 mg of estradiol and 120 mg of trenbolone acetate administered on d 56, BW = 385 kg.
[f]Determined using (empty body fat, kg/empty body weight, kg); regression equation for empty body fat (kg) reported in Table 8.

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