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Effect of weaning status and implant regimen on growth, performance, and carcass characteristics of steers[1]

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ABSTRACT: One hundred forty-three Angus × Simmental crossbred steers (initial BW = 155.1 ± 4.5 kg) were used in a 2-yr study (yr 1, n = 67; yr 2, n = 76) to determine the effects of weaning age, implant regimen, and the weaning age × implant regimen interaction on steer growth and performance, organ mass, carcass characteristics, and cooked beef palatability. Steers were early-weaned at an average age of 108 d (EW) or normally weaned at an average age of 202 d (NW) and allotted by weight to an aggressive or nonaggressive implant regimen. On their respective weaning dates, EW and NW steers were penned individually and fed a grain-based diet until they were slaughtered at a final BW of 546 kg. A subsample of steers (n = 2 per treatment) were slaughtered at 254 kg. At 254 kg, EW steers implanted with the aggressive implant regimen had 64% greater backfat depth than those implanted with the nonaggressive implant regimen; conversely, NW steers implanted with the aggressive implant regimen had 52% lower backfat depth than those implanted with the nonaggressive implant regimen (weaning status × implant regimen interaction; $P < 0.01$). A similar interaction was observed for empty visceral organ weights. Early-weaned steers were younger (354.7 vs 372.4 d; $P < 0.01$) at final slaughter but were in the feedlot longer (246.5 vs 169.6 d; $P < 0.01$) than NW steers, whereas the aggressive implant regimen decreased days fed (203.3 vs 212.7; $P < 0.07$) compared to the nonaggressive implant regimen. Overall ADG was greater for EW than for NW steers (1.61 vs 1.50 kg/d; $P < 0.01$) and for the aggressive compared with the nonaggressive implant regimen (1.59 vs 1.52 kg/d; $P < 0.02$). Early-weaned steers consumed less DM per day (7.4 vs 8.5 kg/d; $P < 0.01$) and were more efficient (0.217 vs 0.208 kg/kg; $P < 0.02$) but consumed more total DM (1,817 vs 1,429 kg; $P < 0.01$) than NW steers while in the feedlot. Implant regimen did not affect DMI ($P > 0.37$) or feed efficiency ($P > 0.15$). Weaning status did not affect carcass characteristics ($P > 0.14$), final empty body composition ($P > 0.25$), or final longissimus muscle composition ($P > 0.18$); however, steaks from EW steers had higher ($P < 0.05$) taste panel tenderness and juiciness ratings than steaks from NW steers. The aggressive implant regimen decreased yield grade ($P < 0.02$), but did not affect quality grade ($P > 0.86$) compared to the nonaggressive implant regimen. Placing early-weaned steers on an aggressive implant regimen is a viable management option.

Key Words: Beef Cattle, Growth Promoters, Weaning

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Introduction

Forage yield and quality can decline in mid- to late summer in many parts of the United States. As a result, cow body condition and milk production can decline. Spring-born calves, therefore, may experience decreased gains at a time when their growth potential is high. Early weaning decreases the nutrient requirements of a mid- to late-lactation cow, therefore increasing cow condition and carrying capacity of the land (Peterson et al., 1987; Myers et al., 1999a,b). However, early-weaned calves may experience slow growth late in the feedlot phase and produce excessively fat, lightweight carcasses that are unacceptable in a value-based marketing system (Williams et al., 1975; Fluharty et al., 2000). Optimal strategies for managing early-weaned calves have not been identified.

Anabolic implants can be used to improve growth rate, feed efficiency, and leanness of cattle, primarily through an increased rate of protein deposition (Hancock et al., 1991). Early-weaned steers may require a

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relatively aggressive implant regimen to increase carcass weight and decrease extramuscular fat accretion (Fluharty et al., 2000). Effects of an aggressive implant regimen on carcass weight, extramuscular and intramuscular fat development, and early visceral organ growth have not been characterized in early-weaned steers. The objective of this experiment was to determine the effects of weaning age, implant regimen, and the interaction of weaning age and implant regimen on performance, composition of growth, carcass characteristics, and cooked beef palatability of steers.

Experimental Procedures

One hundred forty-three Angus × Simmental crossbred steers (initial BW = 155.1 ± 4.5 kg) were used in a 2-yr study (yr 1, n = 67; yr 2, n = 76) to determine the effects of weaning age, implant regimen, and the weaning age × implant regimen interaction on growth, performance, and carcass characteristics. Steers were early-weaned at an average age of 108 d (**EW**) or normally weaned at an average age of 202 d (**NW**) and allotted by weight to an aggressive or nonaggressive implant regimen (2 × 2 factorial arrangement). Steers were castrated at approximately 50 d of age. Early-weaned steers were transported to the OARDC feedlot in Wooster, Ohio on July 2, 1996, or June 25, 1997. Normally weaned steers remained with their dams throughout the summer until October 1, 1996, or September 24, 1997, when they were transported to the OARDC feedlot. Before weaning time (108 and 202 d, respectively) EW and NW steers grazed in southern Ohio on mixed pastures of orchard grass, Kentucky bluegrass, clover, and tall fescue. Two weeks before weaning time, and upon arrival at the feedlot, all steers were vaccinated for protection against infectious bovine rhinotracheitis virus, parainfluenza-3 virus, *Haemophilus somnus*, *Pasteurella*, and Clostridia (Quadraplex, Somnugen 2P, and Dybelon, respectively; Bioceutic, St. Joseph, MO) and dewormed with Ivomec pour-on (Merck, Rahway, NJ). Early-weaned steers were revaccinated when NW steers arrived at the feedlot. Performance of EW and NW cattle was measured in two phases. Phase 1 began at early-weaning time and lasted 92 d; EW steers were in the feedlot and NW steers were on pasture. Phase 2 began at the normal weaning time and ended when steers were slaughtered. Early-weaned and NW steers were both in the feedlot during phase 2. Research protocols regarding animal care followed guidelines recommended in the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (Consortium, 1988).

In yr 2, approximately 1 mo before normal weaning time (162 d of age), NW steer weights were used in an equation, based on their growth rate over the previous 56 d, to determine their predicted 202-d weaning weight. This predicted 202-d weight (254 kg) was used to select two steers from each treatment for initial carcass evaluation. Four EW steers weighing 254 kg were killed at 169 d of age and four NW steers weighing 254 kg were killed at 202 d of age. Early-weaned and NW steers assigned to the nonaggressive implant regimen were not implanted before initial slaughter, and EW and NW steers assigned to the aggressive implant regimen were killed 62 or 63 d after implantation with their original implant. Equal initial slaughter weights among treatments were used to avoid confounding effects of body weight on carcass composition.

Steers assigned to the aggressive implant regimen in yr 1 were implanted with Synovex-C (10 mg estradiol benzoate, 100 mg progesterone; Fort Dodge Animal Health, Overland Park, KS) at an average age of 163 d and Revalor-S (24 mg estradiol, 120 mg trenbolone acetate; Hoechst-Roussel Agri. Vet. Co., Overland Park, KS) at an average age of 204 d and at 295 d (if BW was < 477 kg). Steers assigned to the aggressive implant regimen in yr 2 were implanted with Synovex-C at an average age of 107 d (EW) or 134 d (NW) and Revalor-S at an average age of 170 (EW) or 198 d (NW) and were reimplanted (if BW was < 477 kg) with Revalor-S at 247 (EW) or 275 d (NW). Steers assigned to the nonaggressive implant regimen in yr 1 were implanted with Synovex-S (20 mg estradiol benzoate, 200 mg progesterone) at an average age of 204 d, and at 295 d (if BW was < 477 kg). Steers assigned to the nonaggressive implant regimen in yr 2 were implanted with Synovex-S at an average age of 170 (EW) or 198 d (NW) and were reimplanted (if BW was < 477 kg) with Synovex-S at an average age of 247 (EW) or 275 d (NW). Previous research suggests that if the final implant contains trenbolone acetate and is administered more than once, or too near the date of slaughter, decreased marbling scores and tenderness may result (Foutz et al., 1989); therefore, any steer that was less than 69 kg from the predicted final weight of 546 kg at the final implant date was not reimplanted. Based on data in yr 1, implant age was adjusted in yr 2 to accommodate a final implant in EW steers, to ensure that EW and NW steers would be at similar weights when implanted, and to make sure that EW and NW steers were implanted for a similar amount of time from the last implantation to slaughter.

All steers were penned individually in a totally enclosed feedlot barn. Pen construction consisted of metal gates and a slatted concrete floor. Pens were 2.6 × 1.5 m, giving each steer 3.9 m^2 of space. Steers were fed an 85% concentrate, 17.4% CP receiving diet (Table 1) for the first 14 d. Initially, steers were fed 3.5 kg of DM and intake was gradually increased during the 14-d receiving period. An 85% concentrate, 13.2% CP finishing diet (Table 1) was fed for the remainder of the trial. Steers were offered feed for ad libitum consumption once daily, beginning at 0800, and feed refusals were recorded daily for each steer. Initial and final BW were determined, using the average of BW taken before feeding on two consecutive days. Interim BW were taken every 28 d, before feeding. Average daily gain, DMI, and feed efficiency (gain/feed) were determined for each

Table 1. Diet composition (DM basis)

Item	Year 1 Receiving	Year 1 Finishing	Year 2 Receiving	Year 2 Finishing
Ingredient				
Shelled corn, %	60.000	70.000	60.000	65.000
Corn silage, %	15.000	15.000	15.000	15.000
Ground corn, %	0.483	0.483	—	4.900
Soybean meal, %	20.500	10.500	20.500	10.600
Urea, %	0.500	0.500	0.500	0.500
Limestone, %	1.600	1.600	1.433	1.333
Dicalcium phosphate, %	0.750	0.750	0.400	0.500
Trace mineral salt, %[a]	0.500	0.500	0.500	0.500
Vitamin A, 30,000 IU/g, %	0.010	0.010	0.010	0.010
Vitamin D, 3,000 IU/g, %	0.010	0.010	0.010	0.010
Vitamin E, 44 IU/g, %	0.030	0.030	0.030	0.030
Selenium, 201 mg/kg, %	0.050	0.050	0.050	0.050
Rumensin, 176 g/kg, %[b]	0.017	0.017	0.017	0.017
Potassium chloride, %	0.150	0.150	0.150	0.150
Dynamate, %[c]	0.400	0.400	0.400	0.400
Fat, %[d]	—	—	1.000	1.000
Nutrient composition[e]				
Crude protein, %	17.63	13.33	17.05	13.06
Calcium, %	0.82	0.79	0.69	0.65
Phosphorous, %	0.54	0.50	0.47	0.45
Potassium, %	0.96	0.78	0.95	0.78
NE_m, Mcal/kg	2.02	2.04	2.06	2.08
NE_g, Mcal/kg	1.38	1.39	1.41	1.42

[a]Contained > 93% NaCl, 0.35% Zn, 0.28% Mn, 0.175% Fe, 0.035% Cu, 0.007% I, and 0.007% Co.
[b]Monensin, Elanco, Greenfield, IN.
[c]Magnesium sulfate and potassium sulfate. Contained 22% S, 18% K, and 11% Mg (International Minerals and Chemical, Terre Haute, IN).
[d]Animal and vegetable fat blend.
[e]Crude protein was determined by analysis; remaining composition values were calculated (NRC, 1996).

28-d period, as well as for the entire trial. Feed samples were collected every 7 d throughout the trial and analyzed for DM according to the procedures of Goering and Van Soest (1970). Monthly composites of feed were analyzed for N content using a LECO 2000 N analyzer (LECO Corp., St. Joseph, MI). Neutral detergent fiber and ADF were determined according to the procedures of Van Soest et al. (1991). Health status of the steers was recorded daily. Rectal temperatures were measured in animals with decreased feed intakes, or in those with severe nasal mucous drainage and rapid or labored breathing. Any animal with a rectal temperature > 39.4°C, taken before feeding in the morning, was treated with antibiotics (Micotil, Elanco, Indianapolis, IN; Nuflor, Schering Plough, Union, NJ) according to label instructions. Antibiotic treatment continued until rectal temperature was below 39.4°C.

At early and normal weaning time, steers were scanned between the 12th and 13th rib with an Aloka 500V ultrasound machine (Carometrics Medical Systems, Wallingford, CT) to determine backfat depth and longissimus muscle area. Steers were measured at the hip to determine hip height. Steers were removed from the trial on an individual basis when they reached a BW of 546 kg. Steers were taken to a common terminal BW because carcass fat percentage has been shown to be directly related to carcass weight (Berg and Butterfield, 1967; Waldman et al., 1971; Ferrell et al., 1978). Steers not reaching a minimum slaughter weight of 522 kg and gaining less than 0.5 kg/d for 4 wk or more would not have been able to achieve the target slaughter weight (546 kg) in a reasonable amount of time and were therefore removed from the trial and the statistical analysis. This *a priori* decision was made to mimic practical production situations in which very poorly performing steers would be sold rather than fed indefinitely. Hot carcass weight, backfat depth, percentage of kidney, pelvic and heart fat, longissimus muscle area, and USDA quality and yield grades were determined by qualified OSU personnel 48 h after slaughter. A trained eight-member taste panel (AMSA, 1995) determined measurements for juiciness, tenderness, and flavor intensity, on a cooked section of longissimus muscle from the 13th rib, based on a scale of 1 (extremely dry, extremely tough, or extremely bland, respectively) to 8 (extremely juicy, extremely tender, or extremely intense, respectively). Steaks were cooked to an average internal temperature of 71.7°C and peak Warner-Bratzler shear force was used as a measure of tenderness according to AMSA (1995) recommendations. The 9–10–11th rib section and the longissimus muscle from the 6–7–8th rib was removed from the right side of each carcass. Rib sections (9–10–11th) were deboned, longissimus muscles (6–7–8th) were trimmed of external fat, and both were ground three times and subsampled for determination of moisture, N, and ether-extractable lipid (AOAC, 1984). A conversion factor of 5.72 (Sosulski and Imafidon, 1990) was used to convert N to protein. Regression equations (using the 9–10–11th rib) of Hankins and Howe (1946) were used to determine the chemical composition of the edible carcass. Final empty body composition of steers (254 and 546 kg) was determined using the procedures of Hankins and Howe (1946) and equations of Garrett and Hinman (1969). Procedures and regression equations developed by Hankins and Howe (1946) can be used to accurately predict carcass composition over a wide range of weights (Nour and Thonney, 1994). The gastrointestinal tract was collected on the initial slaughter date only (yr 2), emptied, flushed with water, and allowed to drip dry, and the organs comprising the gastrointestinal tract were weighed.

Data were analyzed using the GLM procedures of SAS (SAS Inst. Inc., Cary, NC) for a randomized complete block design (blocked by year) with a 2×2 factorial arrangement of treatments. The model included effects due to year, weaning status, implant regimen, and the weaning status × implant regimen interaction. Effects due to year were not significant ($P > 0.10$); therefore, data were combined. Residual mean square was the error term and animal was the experimental unit. Effects due to time (performance before 202 d of age vs after 202 d of age), the weaning status × time, and the implant regimen × time interactions were analyzed using the MIXED procedures of SAS (SAS Inst). The covariance structure used was autoregressive and animal was the experimental unit.

Results and Discussion

Phase 1, for both EW and NW steers, began at early weaning time and lasted for 92 d (Table 2). Early-weaned steers gained much faster ($P < 0.01$) and accumulated nearly four times as much backfat thickness ($P < 0.01$) and twice as much longissimus muscle area ($P < 0.01$) as NW steers during phase 1. As a result, EW steers attained a 51.5 kg greater live weight ($P < 0.01$), a 0.30 cm greater backfat depth ($P < 0.01$), and a 9.2 cm^2 larger longissimus muscle area than NW steers at normal weaning time. Early-weaned steers consumed 5.7 kg of DM/d and achieved a gain/feed ratio of 0.285 kg/kg. After approximately 65 d of age, the growth rate of calves may be limited by the cow's milk production and the amount of protein and energy in the cow's milk (Bartle et al., 1984), and available pasture may not be able to support maximum rates of gain; therefore, another source of feed may be necessary. Early weaning before 150 d (Harvey et al., 1975; Myers et al., 1999b; Story et al., 2000), 120 d (Williams et al., 1975; Richardson et al., 1978), 110 d (Peterson et al., 1987; Fluharty et al., 2000), and 67 d of age (Neville and McCormick, 1981) has improved performance from early weaning to normal weaning time, which is in agreement with the present trial. In contrast, Lusby et al. (1981) reported that calves from first-calf heifers weaned from 6 to 8 wk of age and fed in a drylot until 7 mo of age had weights similar to calves from first-calf heifers weaned at 7 mo of age. Weaning calves from first-calf heifers before 9 wk of age may restrict their growth and may not be economical; however, diet energy (34.5 vs 60.0% corn, respectively) and DMI (3.4 vs 5.6 kg/d, respectively) was lower in the study of Lusby et al. (1981) than in the current trial.

Due to a faster growth rate, a greater percentage ($P < 0.02$) of EW steers (14.7%) than of NW steers (3.1%) were above the maximum reimplant weight of 477 kg and did not receive their final implant. Of those steers, 13.0% were implanted with the aggressive implant regimen and 4.9% were implanted with the nonaggressive implant regimen ($P < 0.09$). Steers implanted with the aggressive implant regimen gained 9.5% faster ($P < 0.01$) and accumulated 18.0% more longissimus muscle area ($P < 0.01$) than steers implanted with the nonaggressive implant regimen in phase 1. As a result, steers implanted with the aggressive implant regimen had a 11.0 kg greater live weight ($P < 0.10$), a 2.6 cm^2 greater longissimus muscle area ($P < 0.05$), and a similar amount of backfat ($P > 0.80$) at normal weaning time compared to steers implanted with the nonaggressive implant regimen. Early-weaned steers on the aggressive implant regimen and EW steers on the nonaggressive implant regimen consumed similar amounts of DM ($P > 0.58$) in phase 1; however, EW steers implanted with the aggressive implant regimen were more efficient than EW steers implanted with the nonaggressive implant regimen ($P < 0.01$).

Early-weaned and NW steers implanted with the aggressive implant regimen and slaughtered in phase 1 (169 and 197 d of age, respectively) had been implanted with Synovex-C for 62 and 63 d, respectively. Early-weaned and NW steers implanted with the nonaggressive implant regimen and slaughtered in phase 1 had not been implanted. As was planned, live weight of steers slaughtered in phase 1 was not affected ($P > 0.62$) by weaning status or implant regimen (Table 3). Early-weaned and NW steers had a similar longissimus muscle area ($P > 0.81$), but EW steers had twice as much backfat depth ($P < 0.01$) as NW steers. Differences in carcass composition between EW and NW steers were consistent with differences in backfat thickness. Even though quality grade was not affected by weaning status, longissimus muscle fat percentage, as measured by ether extraction, was 2.7-fold greater ($P < 0.002$) for steers that were EW than for steers that were NW. Intramuscular fat deposition may have been initiated at a young age as a result of early feedlot placement. Longissimus muscle moisture percentage was lower ($P < 0.01$) for EW than for NW steers. Steers implanted with the aggressive implant regimen had a 7.4% greater longissimus muscle area ($P < 0.10$) at a similar backfat depth than steers implanted with the nonaggressive implant regimen. The aggressive implant regimen in-

Table 2. Performance and carcass characteristics of steers (main effects) from early weaning time (108 d of age) until normal weaning time (202 d of age)

	Weaning status		Implant regimen			*P*-value		
Item	EW	NW	A	NA	SE	W[a]	I[b]	W × I
No. of animals	61	66	67	70	—	—	—	—
Age at early weaning time, d	108	111	111	108	3.1	0.37	0.27	0.60
Steers not reimplanted, %	14.7	3.1	13.0	4.9	0.05	0.02	0.09	0.74
Weight at early weaning time, kg	154.1	156.1	155.1	155.1	4.5	0.66	0.98	0.97
Weight at normal weaning time, kg	302.4	250.9	282.2	271.2	6.1	0.01	0.07	0.61
ADG, kg/d	1.61	1.03	1.38	1.26	0.03	0.01	0.01	0.20
Daily DMI, kg/d	5.7	—	5.6	5.7	0.10	—	0.58	—
Total DMI, kg	517.5	—	513.5	521.5	10.2	—	0.58	—
Gain/feed, kg/kg	0.285	—	0.300	0.270	0.005	—	0.01	—
Hip height								
At early weaning, cm[c]	99.8	101.3	100.3	100.8	1.3	0.24	0.63	0.15
At normal weaning, cm	112.5	113.5	113.5	112.5	0.9	0.24	0.31	0.58
Hip height change, cm[c]	12.4	13.7	13.5	12.7	1.0	0.10	0.49	0.67
Backfat depth[d]								
At early weaning, cm	0.25	0.25	0.28	0.25	0.02	0.87	0.21	0.85
At normal weaning, cm	0.66	0.36	0.51	0.51	0.003	0.01	0.81	0.19
Backfat depth change, cm	0.38	0.10	0.25	0.25	0.03	0.01	0.64	0.17
Longissimus muscle area[d]								
At early weaning, cm^2	36.6	36.0	36.6	36.6	1.0	0.51	0.78	0.90
At normal weaning, cm^2	57.6	48.4	54.3	51.7	1.2	0.01	0.03	0.54
Longissimus muscle area change, cm^2	20.9	11.8	17.7	15.0	0.9	0.01	0.01	0.44

[a]Effect due to weaning status.
[b]Effect due to implant regimen.
[c]Year 2 only (n = 65).
[d]Measured via ultrasound.

Table 3. Carcass characteristics at initial slaughter[a] (main effects)

	Weaning status		Implant regimen			*P*-value		
Item	EW	NW	A	NA	SE	W[b]	I[c]	W × I
No. of animals	4	4	4	4				
Hip height, cm	106.0	116.0	111.2	104.6	2.4	0.04	0.90	0.55
Live weight, kg	245.9	249.8	248.3	247.4	5.2	0.63	0.91	0.79
Hot carcass weight, kg	139.3	149.7	143.9	145.0	4.0	0.14	0.86	0.37
Dressing percentage	56.6	59.9	57.9	58.6	0.62	0.02	0.49	0.11
Kidney, pelvic, and heart fat, %	1.63	1.63	1.50	1.75	0.13	1.0	0.23	1.0
Backfat depth, cm	0.41	0.19	0.31	0.29	0.02	0.01	0.40	0.01
Longissimus muscle area, cm^2	50.1	50.6	52.2	48.6	1.18	0.81	0.10	0.32
Quality grade[d]	1.25	1.00	1.25	1.00	0.31	0.37	0.37	0.37
Yield grade	1.9	1.7	1.7	1.9	0.10	0.18	0.13	0.32
Longissimus muscle protein, %[e]	17.9	16.8	17.4	17.3	0.50	0.21	0.95	0.52
Longissimus muscle moisture, %[e]	73.2	77.2	75.0	75.4	0.53	0.01	0.68	0.12
Longissimus muscle fat, %[e]	4.0	1.5	2.7	2.8	0.22	0.01	0.88	0.40
Longissimus muscle ash, %[e]	4.9	4.5	4.9	4.5	0.36	0.52	0.55	0.25
Carcass protein, %[ef]	15.4	17.0	16.3	16.2	0.40	0.05	0.85	0.63
Carcass moisture, %[ef]	61.2	65.1	63.1	63.2	1.0	0.05	0.95	0.76
Carcass fat, %[ef]	21.3	15.2	18.3	18.2	1.2	0.02	0.93	0.84
Carcass ash, %[ef]	2.0	2.8	2.3	2.5	0.22	0.08	0.59	0.28

[a]EW steers were slaughtered at 169 d of age; NW steers were slaughtered at 197 d of age.
[b]Effect due to weaning status.
[c]Effect due to implant regimen.
[d]Standard = 1, Select = 2.
[e]As-is basis.
[f]Determined using equations of Hankins and Howe (1946).

Table 4. Organ mass at initial slaughter[a] (simple effects)

	Early-weaned		Normally-weaned			*P*-value		
Item	A	NA	A	NA	SE	W[b]	I[c]	W × I
No. of animals	4	4	4	4	—	—	—	—
Full GIT, kg[d]	47.9	51.0	49.8	44.6	2.0	0.32	0.65	0.11
Empty GIT, kg[d]	23.5	20.1	19.0	19.9	0.74	0.03	0.16	0.04
Gut fill, kg	24.3	31.0	30.8	24.7	2.3	0.97	0.92	0.05
Liver, kg	4.23	3.71	3.47	3.88	0.25	0.31	0.85	0.14
Heart, kg	1.11	1.15	1.01	1.07	0.11	0.47	0.70	0.93
Rumen/reticulum, kg[e]	4.94	5.26	4.35	4.16	0.28	0.10	0.88	0.55
Omasum, kg[e]	2.03	1.56	1.91	1.55	0.21	0.76	0.12	0.79
Abomasum, kg[e]	1.04	0.81	0.88	0.78	0.17	0.62	0.37	0.70
Small intestine, kg[e]	5.61	4.11	5.10	5.42	0.27	0.36	0.20	0.08
Cecum weight, kg[e]	0.24	0.26	0.19	0.22	0.02	0.06	0.18	0.89
Large intestine, kg[e]	1.85	1.29	1.93	2.22	0.08	0.01	0.16	0.01
Abdominal fat, kg	7.82	6.77	4.58	5.58	0.56	0.02	0.97	0.14

[a]EW steers were slaughtered at 169 d of age; NW steers were slaughtered at 197 d of age.
[b]Effect due to weaning status.
[c]Effect due to implant regimen.
[d]GIT = gastrointestinal tract.
[e]Empty basis.

creased backfat depth 64% (0.50 vs 0.32 cm) compared to the nonaggressive implant regimen in EW steers but decreased it 52% (0.13 vs 0.25 cm) compared to the nonaggressive implant regimen in NW steers (weaning status × implant regimen interaction; $P < 0.01$), indicating that the effect of implant regimen on backfat depth is dependent on plane of nutrition. Effects of weaning status and implant regimen on early development of carcass tissues have not been reported previously.

Full gastrointestinal tract weight was not affected by weaning status or implant regimen (Table 4); however, EW steers fed a high-concentrate diet had a 20.0% heavier ($P < 0.10$) empty rumen/reticulum weight (5.10 vs 4.25 kg, respectively), a 19% heavier ($P < 0.06$) empty cecum weight (0.25 vs 0.21 kg, respectively), and a 44% greater ($P < 0.02$) abdominal (mesenteric + omental) fat weight (7.29 vs 5.08 kg, respectively) than NW steers. As a result, EW steers had a 12.4% heavier ($P < 0.03$) empty gastrointestinal weight (21.8 vs 19.4 kg) at 254 kg than NW steers. In contrast, EW steers had a 31.8% lighter ($P < 0.004$) large intestine weight (1.57 vs 2.07 kg) and a numerically lighter small intestine weight (4.86 vs 5.26 kg) than NW steers. Forage bulkiness and the subsequent increase in intestinal activity in NW steers may have caused the increase in size of the intestine. An increased organ mass is normally associated with decreased efficiency because the animal's maintenance requirements are increased (Fluharty and McClure, 1997). Despite greater rumen/reticulum weights and the resultant heavier total gastrointestinal tract weights, EW steers were more efficient than NW cattle when in the feedlot. Lower intestinal tract weights may have contributed. Implant regimen did not affect ($P > 0.12$) empty organ weights. However, the Synovex-C implant (aggressive implant regimen) increased empty gastrointestinal weight 16.9%, empty small intestine weight 36.5%, and empty large intestine weight 43.4% compared to no implant (nonaggressive implant regimen) in EW steers but decreased them 4.5%, 5.9%, and 13.1%, respectively, compared to no implant (nonaggressive implant regimen) in NW steers (weaning status × implant regimen interaction; $P < 0.04$, $P < 0.08$, and $P < 0.01$, respectively). The effects of weaning status and the interactions of implants and weaning status on weights of the gastrointestinal tract indicate that implants may affect organ function or efficiency of highly metabolically active tissues. The gut is a very active metabolic tissue, and energy required by the gastrointestinal tract constitutes a significant portion of the animal's maintenance energy requirements (Ferrell et al., 1986); therefore, changes in the capacity of the gastrointestinal tract can affect growth and efficiency.

Early-weaned steers did not require treatment for respiratory disease between 108 and 200 d of age. However, during the first 28 d after arrival of the NW steers in the feedlot, 43.5% of EW steers and 37.3% of NW steers required antibiotic treatment for respiratory disease. No mortalities occurred. Phase 2 began for EW and NW steers when all steers averaged approximately 201 d of age and lasted until steers were slaughtered. Average daily gain, hip height change, backfat depth change, and longissimus muscle area change in phase 2 (Table 5) were inversely related to measurements in phase 1 (weaning status × time interaction; $P < 0.01$). However, during phase 2, NW steers had to remain in the feedlot for 15 more days than EW steers ($P < 0.01$) to achieve the same final BW, final hip height, final backfat depth, and final longissimus muscle area, demonstrating that the pattern of growth may be changed, but not the extent of growth. Williams et al. (1975) and Fluharty et al. (2000) observed similar results; however, this is in contrast to Myers et al. (1999 a,b), who did not find that ADG after weaning at 205 d of age was inversely related to ADG before weaning at 205 d of age. Early-weaned steers gained 8.5% slower ($P < 0.01$), and accumulated 27.7% less backfat depth ($P < 0.01$) and 39.2% less longissimus muscle area ($P < 0.01$) than NW steers during phase 2. Early-weaned and NW steers consumed similar amounts of DM in phase 2 ($P > 0.18$); however, EW steers were less efficient than NW steers ($P < 0.01$). Average daily gain, backfat depth change, and longissimus muscle area change were similar ($P > 0.17$) for steers implanted with the aggressive implant regimen compared to steers implanted with the nonaggressive implant regimen; however, steers implanted with the aggressive implant regimen were in the feedlot for 9 fewer days ($P < 0.07$). Implant regimen did not affect daily DMI; however, because steers implanted with the aggressive implant regimen spent fewer days in the feedlot, they consumed 61.3 fewer kilograms of feed ($P < 0.08$) than steers implanted with the nonaggressive implant regimen. The difference in ADG between steers implanted with the aggressive and nonaggressive implant regimens decreased from 9.5% in phase 1 to 3.0% in phase 2 (implant regimen × time interaction; $P < 0.01$). Steers implanted with the aggressive implant regimen increased their hip height to a lesser extent than steers implanted with the nonaggressive implant regimen; therefore, hip height change in phase 2 was inversely related to hip height change in phase 1 (implant regimen × time interaction; $P < 0.01$). As a result, steers implanted with the aggressive implant regimen were 1.2 cm shorter ($P < 0.04$) than steers implanted with the nonaggressive implant regimen, indicating that implant regimen may affect skeletal growth.

At slaughter, early-weaned steers were 18 d younger but were in the feedlot 77 d longer ($P < 0.01$) than NW steers (Table 6). This is in agreement with Myers et al. (1999b), who demonstrated that early-weaned steers were fed for 55 to 93 d longer than steers that were normally weaned or normally weaned and creep-fed, and with Story et al. (2000), who reported that early-weaned steers were fed for 43 d more than normally weaned steers. Even though EW steers gained slightly slower ($P < 0.01$) and accumulated less ($P < 0.01$) longissimus muscle area than NW steers while in the feedlot (108 d of age to slaughter for EW steers; 202 d of age to slaughter for NW steers) in this trial, they gained 7.3% faster ($P < 0.01$) and accumulated similar amounts of backfat when data from 108 to 202 d of age were included for NW steers. As a result, EW steers achieved a similar final BW and a similar final backfat thickness but had a 2.0 cm^2 smaller longissimus muscle area than NW steers ($P = 0.13$). However, 4.9% of EW steers, 6.1% of NW steers, 3.3% of steers implanted with the aggressive implant regimen, and 7.7% of steers implanted with the nonaggressive implant regimen could not reach 522 kg and were removed from the statistical analysis because they were gaining less than 0.5 kg/d for a prolonged period of time. All NW steers removed were implanted with the nonaggressive implant regimen (12.2% of all steers), whereas only a third of the EW steers removed (3.2% of all steers) were implanted with the nonaggressive implant regimen (weaning status × implant regimen interaction; $P < 0.04$). Two-thirds of the EW steers removed (6.6% of all steers) were implanted with the aggressive implant regimen. Contributing factors to this interaction have not been determined; perhaps decreased performance of these steers was a result of excessive fat deposition. Early removal of an animal can represent an important economic loss to producers; however, removing the poorest-performing cattle from each treatment would tend to make

Table 5. Performance and carcass characteristics of steers from normal weaning time (202 d of age) until slaughter (main effects)

	Weaning status		Implant regimen			*P*-value		
Item	EW	NW	A	NA	SE	W[a]	I[b]	W × I
Days in feedlot	155.0	169.6	157.6	167.0	5.30	0.01	0.07	0.58
Age at normal weaning, d	200	202	202	200	3.6	0.65	0.55	0.40
Weight at normal weaning, kg	302.4	250.9	282.2	271.2	6.1	0.01	0.07	0.61
Final weight, kg	546.0	545.4	546.3	545.0	2.0	0.74	0.50	0.91
ADG, kg[cd]	1.61	1.76	1.71	1.66	0.04	0.01	0.29	0.64
Daily DMI, kg	8.7	8.5	8.7	8.5	0.1	0.18	0.21	0.03
Total DMI, kg	1,316.8	1,428.5	1,342.0	1,403.3	36.3	0.01	0.08	0.75
Gain/feed, kg/kg	0.186	0.208	0.198	0.196	0.004	0.01	0.67	0.23
Hip height at slaughter, cm	129.3	129.5	128.8	130.0	0.6	0.73	0.04	0.64
Phase 2 hip height change, cm[cd]	16.8	16.0	15.2	17.5	0.7	0.26	0.01	0.26
Backfat depth at slaughter, cm[c]	1.47	1.47	1.42	1.52	0.08	0.99	0.21	0.57
Phase 2 backfat depth change, cm[ce]	0.81	1.12	0.91	1.02	0.08	0.01	0.17	0.30
Longissimus muscle area at slaughter, cm^2 [cd]	76.5	78.5	79.2	75.9	1.4	0.13	0.02	0.23
Phase 2 longissimus muscle area change, cm^2 [ce]	18.3	30.1	24.9	24.2	1.6	0.01	0.61	0.15

[a]Effect due to weaning status.
[b]Effect due to implant regimen.
[c]Weaning status × time interaction ($P < 0.01$).
[d]Implant regimen × time interaction ($P < 0.01$).
[e]Measured at 202 d of age via ultrasound; final measured on carcass.

Table 6. Performance and carcass characteristics from early weaning time (108 d of age) until slaughter (main effects)

	Weaning status		Implant regimen			*P*-value		
Item	EW	NW	A	NA	SE	W[a]	I[b]	W × I
Days in feedlot	247	170	203	213	5.3	0.01	0.07	0.58
Steers not reaching 522 kg, %	4.9	6.1	3.3	7.7	0.04	0.76	0.24	0.04
Age at slaughter, d	355	372	361	366	5.5	0.01	0.29	0.86
Overall ADG, kg	1.61	1.50	1.59	1.52	0.03	0.01	0.02	0.32
ADG in the feedlot, kg[c]	1.61	1.76	1.71	1.66	0.04	0.01	0.11	0.31
Daily DMI, kg[c]	7.4	8.5	8.0	7.9	0.1	0.01	0.37	0.04
Total DMI, kg[c]	1,817.4	1,428.6	1,599.0	1,646.9	34.4	0.01	0.15	0.45
Feedlot gain/feed, kg/kg[c]	0.217	0.208	0.215	0.210	0.004	0.02	0.22	0.72
Overall hip height change, cm[d]	27.94	27.43	27.18	28.19	1.22	0.60	0.32	0.11
Overall backfat depth change, cm[e]	1.22	1.22	1.17	1.27	0.08	0.88	0.17	0.66
Overall longissimus muscle change, cm^2 [e]	39.3	41.9	42.5	39.3	1.6	0.08	0.02	0.32

[a]Effect due to weaning status.
[b]Effect due to implant regimen.
[c]For feedlot phase only. EW in feedlot from 108 d of age until slaughter; NW in feedlot from 202 d of age until slaughter.
[d]Year 2 only (n = 65).
[e]Measured at 108 d of age via ultrasound; final measured on carcass.

treatment differences less pronounced. Problems with excessive fat deposition in early-weaned steers have been documented (Gill et al., 1993b; Fluharty et al., 2000). The fact that steers were not implanted by Fluharty et al. (2000) and Gill et al. (1993b) may have contributed to excessive fat accretion. Williams et al. (1975) also demonstrated that, when slaughtered at a constant age end point (52 to 53 wk of age), early-weaned bulls had more backfat but had greater carcass value than normally weaned bulls, partly due to heavier (272.5 vs 262.1 kg) and higher-grading carcasses.

Gill et al. (1993a) determined that ADFI in the feedlot, whether expressed as quantity per day or as a percentage of BW or metabolic size, was lower for early-weaned and normally weaned cattle that went directly into the feedlot than for cattle that were placed on pasture after weaning at 205 d of age, partly due to lighter mean feedlot weight. In the present trial, EW steers consumed 12.9% less DM/d ($P < 0.01$) and were 4.3% more efficient ($P < 0.02$) than NW steers when in the feedlot because they consumed more feed when their maintenance energy requirements were low (NRC, 1996). However, EW steers consumed 27.2% more total DM ($P < 0.01$) than NW steers because they were in the feedlot longer. Myers et al. (1999a) also reported that when in the feedlot, early-weaned steers consumed less DM per day and were more efficient, but they consumed more total DM than steers that were normally weaned (151 kg more) and steers that were normally weaned and creep-fed (217 kg more). Lower maintenance energy requirements and more days spent in the feedlot for early-weaned steers in Myers et al. (1999a) were contributing factors as well. Story et al. (2000) observed similar results. Increased cow condition or carrying capacity of pasture could offset the added cost of feed incurred by feeding steers early-weaned at approximately 100 d of age. Peterson et al. (1987) reported that early-weaned (110 d of age) cow-calf pairs consumed 20.4% less TDN and were 43% more efficient in converting TDN into calf gain than were normally weaned (222 d of age) cow-calf pairs. Cows with more body condition during gestation require less supplemental feed, can be maintained at a lower cost, and may be better prepared for subsequent calving seasons and lactation than cows with less body condition (Peterson et al., 1987).

Steers implanted with the aggressive implant regimen were in the feedlot for 9 fewer days ($P < 0.07$) than steers implanted with the nonaggressive implant regimen, but age at slaughter did not differ ($P > 0.29$) between implant treatments. Implant regimen had no effect on total DMI; however, the aggressive implant regimen increased daily DMI 4.1% (7.6 vs 7.3 kg) compared to the nonaggressive implant regimen in EW steers but decreased it 1.2% (8.4 vs 8.5) compared to the nonaggressive implant regimen in NW steers (weaning status × implant regimen interaction; $P < 0.04$), indicating that an aggressive implant regimen may be more effective at increasing intake in young, rapidly growing steers. Steers implanted with the aggressive implant regimen gained faster ($P < 0.02$) and accumulated similar amounts of backfat depth ($P > 0.17$) but has increased ($P < 0.02$) longissimus muscle area compared to steers implanted with the nonaggressive implant regimen from early weaning time until slaughter. Thus, steers implanted with the aggressive implant regimen produced carcasses with a 4.3% larger longissimus muscle area ($P < 0.02$) at a similar final backfat depth, compared to carcasses from steers implanted with the nonaggressive implant regimen.

Hot carcass weight, dressing percentage, kidney, pelvic, and heart fat percentage, and yield grade were not affected ($P > 0.29$) by weaning status (Table 7). Story et al. (2000) reported similar results and observed that weaning status did not affect net income per steer. In contrast, when early-weaned and normally weaned bulls were fed to a common end point of 52 to 53 wk of age, Williams et al. (1975) observed that early-weaned bulls produced carcasses that were 4.0% heavier than carcasses from normally weaned bulls. In our study, yield grade was lower ($P < 0.02$) for carcasses from steers implanted with the aggressive implant regimen compared to carcasses from steers implanted with the nonaggressive implant regimen. Early-weaned, NW, and aggressive and nonaggressive implant main effects resulted in 93.7, 85.2, 90.3, and 88.6% of carcasses grading Choice, respectively, suggesting that young, aggressively implanted steers can deposit enough marbling to grade Choice. Marbling score and percentage Choice were not different ($P > 0.14$) between EW and NW steer carcasses or between carcasses from steers on the aggressive or nonaggressive implant treatments. Carcass composition (9–10–11th rib) and longissimus muscle composition (6–7–8th rib) were not affected by weaning status ($P > 0.18$). Steers assigned to the aggressive implant regimen accumulated a higher ($P < 0.07$) percentage of carcass and longissimus muscle protein, a higher ($P < 0.09$) percentage of carcass moisture, and a lower ($P < 0.07$) percentage of carcass fat with no effect ($P > 0.15$) on the percentage of longissimus muscle fat, indicating that nutrients may have been partitioned more toward muscle growth than extramuscular fat growth, whereas intramuscular fat was not affected. Implant regimen did not affect the percentage of carcass or longissimus muscle ash or the percentage of longissimus muscle moisture ($P > 0.20$). In EW steers, the aggressive implant regimen increased carcass protein by 0.6 percentage points (14.3 vs 13.7%) compared to the nonaggressive implant regimen but in NW steers increased it only 0.1 percentage point (14.2 vs 14.1%; weaning status × implant regimen interaction; $P < 0.04$), indicating that an aggressive implant regimen may be more effective at increasing muscle in young, rapidly growing steers.

Warner-Bratzler shear force of the cooked longissimus muscle of the 13th rib was not affected ($P > 0.17$) by weaning status or implant regimen. In contrast, Foutz et al. (1997) observed that steaks from carcasses of implanted steers had higher shear force values than steaks from carcasses of unimplanted steers. In the present study, when measured by a trained taste panel, EW steers produced steaks that were more tender ($P < 0.05$) and more juicy ($P < 0.04$) than steaks from NW steers, with no effect ($P > 0.43$) on flavor intensity. The enhanced palatability of cooked steaks from EW steers compared to NW steers may result from a greater num-

Table 7. Final carcass characteristics, final carcass composition, and sensory evaluation (main effects)

	Weaning status		Implant regimen			*P*-value		
Item	EW	NW	A	NA	SE	W[a]	I[b]	W × I
Hot carcass weight, kg	332.4	331.1	331.7	331.9	1.6	0.39	0.87	0.85
Dressing percentage	61.0	60.6	60.7	60.9	0.27	0.35	0.48	0.71
Kidney, pelvic, and heart fat, %	3.5	3.5	3.5	3.5	0.08	0.55	0.90	0.17
Yield grade	3.7	3.6	3.5	3.8	0.12	0.29	0.02	0.94
Marbling score[c]	444.3	440.0	439.2	445.1	20.20	0.83	0.76	0.13
Quality grade[d]	4.0	3.9	3.9	4.0	0.20	0.81	0.86	0.15
Select, %	6.3	14.8	9.7	11.4	0.13	0.14	0.77	0.86
≥ Choice, %	93.7	85.2	90.3	88.6	0.06	0.14	0.77	0.86
≥ Average choice, %	60.3	69.1	61.1	68.3	0.71	0.31	0.39	0.16
≥ High choice, %	34.5	34.1	35.4	33.2	0.09	0.96	0.81	0.13
Prime, %	8.5	3.9	6.2	6.3	0.04	0.29	0.98	0.52
Carcass protein, %[ef]	14.0	14.2	14.2	13.9	0.14	0.25	0.02	0.04
Carcass moisture, %[ef]	51.3	51.5	51.8	51.0	0.47	0.67	0.09	0.35
Carcass fat, %[ef]	33.1	32.8	32.4	33.5	0.62	0.55	0.07	0.38
Carcass ash, %[ef]	1.6	1.6	1.6	1.6	0.12	0.95	0.99	0.12
Longissimus muscle protein, %[f]	18.3	18.4	18.3	18.4	0.10	0.71	0.07	0.15
Longissimus muscle moisture, %[f]	70.7	70.9	70.8	70.9	0.28	0.32	0.70	0.26
Longissimus muscle fat, %[f]	7.7	7.3	7.7	7.3	0.28	0.18	0.15	0.15
Longissimus muscle ash, %[f]	3.3	3.4	3.3	3.4	0.09	0.48	0.20	0.55
Shear force, kg	4.8	5.1	5.0	4.9	0.20	0.17	0.62	0.50
Tenderness[g]	5.8	5.4	5.5	5.7	0.19	0.05	0.14	0.94
Juiciness[g]	5.7	5.4	5.5	5.5	0.14	0.04	0.82	0.87
Flavor intensity[g]	5.5	5.4	5.5	5.4	0.09	0.43	0.31	0.36

[a]Effect due to weaning status.
[b]Effect due to implant regimen.
[c]Practically devoid = 100–199, slight = 200–299, small = 300–399, modest = 400–499, moderate = 500–599.
[d]Standard = 1.0, Select = 2.0, Choice$^-$ = 3.0, Choice° = 4.0, Choice$^+$ = 5.0, Prime$^-$ = 6.0.
[e]Determined using the equations of Hankins and Howe (1946).
[f]As-is basis.
[g]1 = extremely tough, extremely dry, extremely bland; 8 = extremely tender, extremely juicy, extremely intense.

ber of days on high-concentrate feed, a younger slaughter age, or a combination of these factors. Implant regimen did not affect ($P > 0.14$) tenderness, juiciness, or flavor intensity of steaks as measured by taste panel, indicating that implant regimens containing similar implants do not affect sensory characteristics.

Williams et al. (1975), Myers et al. (1999a), and Fluharty et al. (2000) demonstrated that early-weaning steers and immediately placing them on a high-concentrate diet can increase extramuscular and intramuscular fat deposition. In contrast, steroid implants promote growth primarily through increasing the rate of protein deposition, with minimal effects on lipid metabolism (Buttery and Sinnett-Smith, 1984). Implanting cattle fed for the same number of days has been shown to decrease backfat depth and marbling scores to different degrees, depending on the type of implant used, but no relationship between quality grade and yield grade existed (Bartle et al., 1992; Herschler et al., 1995; Samber et al., 1996). Because trenbolone-acetate/estradiol implants increase carcass weight and muscle deposition (Anderson, 1991), an increased longissimus muscle area associated with implanted cattle may proportionately decrease intramuscular fat (Duckett et al., 1999) if cattle are slaughtered after a similar number of days, rather than at a common compositional end point. Marbling is thought to be a later-maturing fat depot in cattle managed in a normal weaning system (Anderson, 1991); therefore, it may be underdeveloped in implanted compared to unimplanted steers fed a similar number of days. However, marbling may be equally developed in implanted and unimplanted steers fed to a common compositional end point (Foutz et al., 1997). Anderson (1991) speculated that decreased quality grades, associated with implanting, may only be a function of experimental design. Implant regimen did not affect quality grade in this trial, even though steers implanted with the aggressive implant regimen had a larger longissimus muscle area and were leaner than steers implanted with the nonaggressive implant regimen. In addition to the fact that longissimus muscle fat was increased 2.7-fold in EW compared to NW steers at initial slaughter, these results suggest that young steers fed a high-concentrate diet throughout the feeding period may achieve appreciable amounts of intramuscular fat before aggressive implantation. This refutes the theory that intramuscular fat is a late-maturing fat depot and may explain why early-weaned steers that are aggressively implanted can achieve high quality grades at less than 1 yr of age.

Implications

Placing early-weaned steers on an aggressive implant regimen is a viable management option. Early-weaned steers required a greater total amount of high-concentrate feed to achieve the same final weight as normally-weaned steers; however, they converted feed more efficiently and gained faster from 108 d of age until slaughter than normally-weaned steers and yielded desirable carcasses that produced cooked steaks with greater palatability. Increases in growth rate for early-weaned cattle are primarily due to increases in carcass fat and empty gastrointestinal weight. Early weaning and feeding a high-concentrate diet may also allow appreciable amounts of intramuscular fat deposition to occur early in the feeding period. This could enhance quality grade regardless of age at slaughter and implant regimen. Early weaning and feeding a high-concentrate diet for a prolonged finishing period may cause a small percentage of animals to have poor performance.

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