Effects of repetitive use of hormonal implants on beef carcass quality, tenderness, and consumer ratings of beef palatability[1,2]

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ABSTRACT: Effects of repetitive use of anabolic implants on beef carcass quality, tenderness, and consumer ratings for palatability were investigated using crossbred steer calves (n = 550). Steers from five ranches were randomly allocated to one of 10 different lifetime implant strategies or to a nonimplanted control group. Cattle were implanted at some or all of five phases of production (branding, weaning, backgrounding, feedlot entry, or reimplant time). Carcasses from the control group had higher ($P < 0.05$) marbling scores than carcasses from steers in all other treatment groups. Implanting steers at branding, weaning, or backgrounding vs. not implanting steers at these production stages did not affect ($P > 0.05$) marbling scores. Steers implanted twice during their lifetime produced carcasses with higher ($P < 0.05$) marbling scores than did steers receiving a total of four or five implants. Steaks obtained from carcasses in the control group had lower ($P < 0.05$) shear force values and were rated by consumers as more desirable ($P < 0.05$) for tenderness like/dislike than steaks obtained from carcasses in all other treatment groups. Implanting steers at branding or weaning production stages did not affect ($P > 0.05$) steak shear force values, consumer ratings for like/dislike of steak tenderness, or percentage of consumers rating overall eating quality of steaks as satisfactory. Implanting steers at backgrounding vs. not implanting steers at this production stage increased ($P < 0.05$) steak shear force values, but did not influence ($P > 0.05$) consumer ratings for like/dislike of steak tenderness or percentage of consumers rating overall eating quality of steaks as satisfactory. Steaks from nonimplanted steers were rated as more desirable ($P < 0.05$) for overall eating quality than steaks from steers implanted two, three, four, or five times. Use of implants increased ($P < 0.05$) average daily gain by 11.8 to 20.5% from weaning to harvest compared with nonimplanted controls. Implant strategies increased ($P < 0.05$) hot carcass weight of steers by 8.9 to 13.8% compared with the control group. Use of implants also increased ($P < 0.05$) longissimus muscle area and decreased ($P < 0.05$) estimated percentages of kidney/pelvic/heart fat, but did not affect ($P > 0.05$) dressing percentage or adjusted fat thickness. Our findings suggest that beef quality, palatability, and production characteristics are influenced by lifetime implant protocols.

Key Words: Beef, Carcasses, Growth Promoters, Palatability, Tenderness

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Introduction

Growth-promoting implants are used routinely by U.S. beef producers to increase rate and efficiency of growth in cattle. Currently, there are 16 different commercial implant products approved for use in cattle by the U.S. FDA (Eng, 2000). Hormonal implants are approved for use in cattle of all ages and may be used to enhance growth during the suckling, growing, and finishing phases of production. Therefore, steers and heifers destined for finishing and harvest may receive as many as four to six (or possibly more) implants throughout their lifetime (Mader, 1997).

The benefits of using implants to improve growth performance of cattle are well documented. However, research suggests that "aggressive" and/or repetitive use of implants may be detrimental to beef carcass quality and tenderness (Tatum, 1993; Morgan, 1997; Roeber et al., 2000a). The 1991 and 2000 National Beef Quality Audits both identified "reduced quality of beef due to implants" as one of the packing industry's top six concerns about the quality of beef (Smith et al., 1992; Roeber et al., 2000b).

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Table 1. Description of sample population and simple means for carcass and production traits of steers stratified by ranch

	Ranch					
Item/Trait	1	2	3	4	5	Pooled SD
Ranch location	Wyoming	Texas	Idaho	Wyoming	Wyoming	
Cattle breed type	English (75%) × Continental (25%)	Santa Gertrudis	English	English (≥75%) × Continental (≤25%)	English (≥75%) × Continental (≤25%)	
Number of steers	113	116	107	144	70	—
Weaning weight, kg	228	219	168	174	168	40.0
Final live weight, kg	585	578	569	572	564	49.0
Carcass weight, kg	369	364	359	358	351	32.3
Fat thickness, cm	1.55	1.40	1.47	1.50	1.52	0.41
Ribeye area, cm^2	84.8	83.5	80.3	84.8	82.2	7.96
Calculated yield grade	3.3	3.2	3.4	3.2	3.3	0.66
Marbling[a]	475	380	465	474	515	104.0
Choice and Prime, %	74.3	31.0	72.0	76.9	88.0	—
Number of harvest dates	2	3	2	3	3	—
Days between first and last harvest dates	27	43	28	48	48	—

[a]300 = slight, 400 = small, 500 = modest.

A number of studies have documented the effects of implants administered to steers and heifers during the finishing phase of production on carcass quality and beef tenderness (Samber et al., 1996; Morgan, 1997; Roeber et al., 2000a). However, few studies have examined the possible effects of implants given during the suckling and growing phases of beef production on carcass quality and tenderness. This study was designed to examine the effects of administering growth promoting implants, at sequential stages of production, up to five times during the lifetime of steers, on carcass quality traits, beef tenderness, and consumer ratings of beef palatability.

Materials and Methods

Animals and Experimental Treatments

Five hundred fifty crossbred steer calves (representing a variety of biological cattle types) were obtained from five ranches (located in three states) for use in this study (Table 1). Calves were either allocated to one of 10 different lifetime implant treatment groups or to an untreated, negative control group (50 calves/group; Table 2). The steers were implanted, according to their respective treatments, at some or all of five phases of production (branding, weaning, backgrounding, feedlot entry, and reimplant time during the finishing phase). Implant products used at the various phases of production included Synovex-C (10 mg of estradiol benzoate, 100 mg of progesterone) at branding; Ralgro (36 mg of zeranol) at weaning; Ralgro or Synovex-S (20 mg of estradiol benzoate, 200 mg of progesterone) at backgrounding; Synovex-S or Revalor-S (24 mg of 17-β estradiol, 120 mg of trenbolone acetate) during finishing.

Finishing-phase implant protocols for treatment groups 2, 3, 4, 6, 7, 8, 9, and 10 were standardized (Synovex-S at feedlot entry followed by Revalor-S at reimplant time) to permit direct examination of the effects of implants, which were administered during the suckling and growing phases of production, on carcass quality traits, tenderness, and consumer ratings of palatability. Treatment 11 (Table 2) steers received two Revalor-S implants to represent an “aggressive” feedlot implant protocol, and treatment five (Table 2) steers did not receive an implant upon feedlot entry to represent a lifetime implant program designed for moderate improvements of production performance for steers destined for marketing on a value-based marketing grid (Rains, 1998).

In addition to the individual treatment comparisons, the experiment was designed to contrast the effects of either receiving implants or not receiving implants at each successive prefinishing phase of production (branding, weaning, and backgrounding). To examine the effects of the administration of implants at branding, data obtained from steers in treatments 3, 4, and 6 (no branding implant; Table 2) were pooled and contrasted with pooled data from steers in treatments 7, 8, and 10 (implanted at branding). In these contrasts, subsequent implants for treatments 7, 8, and 10 were exactly the same as those received by treatments 3, 4, and 6, respectively. To examine the effects of an implant received at weaning, pooled data obtained from steers in treatments 4, 7, and 8 (no weaning implant; Table 2) were contrasted with pooled data from steers in treatments 6, 9, and 10 (implanted at weaning). Again, implants administered at all other production phases besides weaning were identical for treatments 6, 9, and 10 as those received by treatments 4, 7, and 8, respectively. Effects of a backgrounding implant were determined by contrasting pooled data from steers in treatment 2 (no implant at backgrounding; Table 2) with pooled

Table 2. Experimental design outlining implant strategy, number of implants administered, and number of steers for each treatment group

Item	Experimental treatment group[a]										
	1	2	3	4	5	6	7	8	9	10	11
Implant at branding	NO	NO	NO	NO	C	NO	C	C	C	C	C
Implant at weaning	NO	NO	NO	NO	NO	RA	NO	NO	RA	RA	RA
Implant at backgrounding	NO	NO	RA	S	S	S	RA	S	RA	S	S
Implant at feedlot entry	NO	S	S	S	NO	S	S	S	S	S	REV
Re-implant in feedlot	NO	REV	REV	REV	REV	REV	REV	REV	REV	REV	REV
Total number of implants administered	0	2	3	3	3	4	4	4	5	5	5
Treatments used for branding phase contrast[b]	—	—	O	O	—	O	X	X	—	X	—
Treatments used for weaning phase contrast[b]	—	—	—	O	—	X	O	O	X	X	—
Treatments used for backgrounding phase contrast[b]	—	O	X	X	—	—	—	—	—	—	—
No. of steers Ranch 1	9	10	10	10	11	10	10	10	11	11	11
No. of steers Ranch 2	11	11	11	11	10	11	11	11	10	9	10
No. of steers Ranch 3	10	10	10	10	9	10	10	10	10	9	9
No. of steers Ranch 4	13	13	13	13	13	13	13	13	13	14	13
No. of steers Ranch 5	7	6	6	6	7	6	6	6	6	7	7
Total number of steers	50	50	50	50	50	50	50	50	50	50	50

[a]Abbreviations used: NO = no implant; C = Synovex-C (10 mg of estradiol benzoate, 100 mg of progesterone); RA = Ralgro (36 mg of zeranol); S = Synovex-S (20 mg of estradiol benzoate, 200 mg of progesterone); REV = Revalor-S (24 mg of 17-β estradiol, 120 mg of trenbolone acetate).
[b]Within each row, data from treatments coded with an X were pooled and contrasted with pooled data from treatments coded with an O.

data from steers in treatments 3 (Ralgro implant at backgrounding) and 4 (Synovex-S at backgrounding). The design of this study also provided an opportunity to analyze the effects of the number of implants (zero, two, three, four, or five implants) administered throughout the lifetime of steers, without consideration of the timing of implanting (Table 2).

Cattle Management

Industry-recommended protocols for proper implant placement and implant equipment sanitation, designed to minimize implanting defects, were used throughout the course of this study (Zero Defect Implanting, Vetlife, Des Moines, IA). Implants were administered subcutaneously in the middle one-third of the left ear at branding, and implant placement was alternated to the same location in the opposite ear at each subsequent processing phase. Implant needles were disinfected after each use using a sponge soaked in 2% chlorenhexadine solution. At branding, male calves (approximately 60 to 100 d old) at each of the five ranches were castrated and randomly assigned to two groups (implanted and nonimplanted). Additional cattle, more than the number specified in the protocol, were identified and included in the study at branding to ensure that an adequate number of steers would be available in each treatment group for analysis at harvest in the event that uncontrolled circumstances caused loss of animals from the study. Because processing conditions on the ranches prevented the measurement of individual calf weights, hoof circumference was measured using a Calf-Scale (Ames, IA) measuring tape at the time of branding in an attempt to quantify the size and/or age of the steer at that time. The tape measurements and the treatments applied at branding (implanted and nonimplanted) were used to allocate, in a balanced fashion, steers in each contemporary group to one of the 11 different implant protocols used in the study (Table 2). Steers were allowed to remain with their dams until weaning at approximately 240 d of age, at which time the calves were individually weighed and implants were administered to steers according to their respective treatment groups.

Within 2 wk after weaning, steers from each ranch were transported to the same commercial feedlot in eastern Colorado for growing and finishing. Upon arrival at the feedlot, steers were processed with normal receiving procedures employed by that feedlot, including a seven-way *Clostridial* vaccination, a vaccination for infectious bovine rhinotracheitis virus (**IBR**), bovine virus diarrhea (**BVD**), bovine respiratory syncytial virus (**BRSV**), and treatment for internal and external parasites. After processing, steers from each ranch were placed in large pens (one ranch's cattle per pen) and started on a low-concentrate grower diet, which consisted of 55.7% beet pulp, 17% ground alfalfa hay, 15% dry rolled corn, 10% distiller's grains (wet), and 2.3% liquid supplement. The initiation of the backgrounding period was delayed 45 to 48 d (depending upon ranch) postweaning. This lag period between weaning and backgrounding represented the acclimation period normally associated with cattle that have been "preconditioned" for the feedlot.

At the initiation of the backgrounding phase, steers (approximately 285 d old) were individually weighed and those scheduled for implanting were implanted according to their respective treatment assignment. After implanting, the pens of steers were allowed to consume the grower diet for an additional period of 64 to 102 d; termination of the backgrounding period for each pen was determined by back-calculating 150 d from a projected average harvest date for all the steers derived from each ranch.

At the initiation of the finishing period, steers were individually weighed and implanted according to their respective implant protocols. During the finishing period, energy levels in the diet were gradually increased (over a 14-d period) from the low-concentrate grower diet to a high-concentrate finishing diet via a six-level "step-up" program. On d 14 of the "step-up" program, cattle were started on the finishing diet, which consisted of 67% dry rolled corn, 15% distiller's grains (wet), 10% beet pulp, 5% liquid supplement, and 2.5% ground alfalfa hay.

Dates for reimplanting during the finishing phase were determined for the steers from each ranch by back-calculating 80 d from a projected average harvest date for all cattle derived from each ranch. At reimplanting, steers were individually weighed and all cattle, except those in the nonimplanted control group, were given a Revalor-S implant.

Steers were harvested when they individually attained 12 to 16 mm of fat thickness over the longissimus muscle at the 12th rib (measured using real-time ultrasound). Because of the difference in age and biological type of the steers obtained from each ranch, not all ranches were represented at each harvest date (Table 1). However, harvest groups from each ranch consisted of steers from all 11 treatment groups, and the average number of days on feed for steers obtained from each ranch was not different across treatments (data not shown). When USDA quality grade is of concern, suppliers of implants containing trenbolone acetate (**TBA**) have recommended a one-time administration of these products 80 to 100 d before harvest (Intervet, 2000). In this study, administration of the terminal TBA combination implant occurred at an average of 82 d ± 10.5.

Carcass Data Collection and Sampling Methods

On each shipping date, steers in each harvest group were weighed individually, transported approximately 80 km to a commercial beef packing plant, and harvested using conventional procedures. Carcasses were chilled in a cooler with an air temperature of 2°C for 36 h and sprayed intermittently (2 min on, 8 min off) with a fine mist of 2°C water for the first 8 h of the chill period. Following the carcass-chilling period, a panel of three Colorado State University personnel independently obtained carcass grade data. Each evaluator independently recorded measurements/assessments of fat thickness, longissimus muscle area, percentage of kidney, pelvic, and heart fat, lean maturity, skeletal maturity, overall carcass maturity, and marbling score for each carcass. Values for each trait from the three evaluators were averaged, resulting in a single value for each factor for every carcass. The 550 carcasses used in the study were chosen randomly from the steers in the trial that had maintained appropriate experimental treatment protocols throughout their lifetime.

Strip loins (IMPS 180; USDA, 1988) from the right sides of the 550 carcasses were collected after fabrication and transported immediately to the Colorado State University Meat Laboratory. At the Meat Laboratory, the anterior end of each strip loin was "faced" and one 2.54-cm steak was removed, placed in a vacuum-sealed bag, and aged at 2°C for 21 d postmortem. The remainder of the strip loin was placed in a vacuum-sealed bag and aged at 2°C for 14 d postmortem. After reaching the appropriate length of aging time, samples were frozen and stored at –20°C for subsequent shear force determination (performed on 14- and 21-d samples) and consumer panel analysis (performed on 14-d samples, only).

Subsamples of strip loins aged for 14 d were fabricated (in the frozen state) into steaks (2.54 cm) with a band saw (model 5700, Hobart, Troy, OH). The first steak from the anterior end of each strip loin section was identified and placed in an individual vacuum-sealed bag for Warner-Bratzler shear force determination. The next two steaks were identified and vacuum-packaged individually for subsequent untrained, consumer taste panel analysis. Upon completion of fabrication of the 14-d-aged subsamples, the steaks were sorted for intended use and returned to frozen storage (–20°C). Samples used for sensory analysis were stored for approximately 180 d at frozen temperatures.

Tenderness Measurements

For shear force determination, frozen steaks were thawed at approximately 2°C for 24 h and cooked on an electric conveyor grill (model TBG-60, Magikitch'n, Quakertown, PA) to a target internal temperature of 70°C. The steaks were cooked for a constant time of 6 min, 35 s at a setting of 176°C for the top and bottom heating platens. Peak internal temperature measurements were recorded for each steak using a Type K thermocouple (model 39658-K, Atkins Technical, Gainesville, FL). After cooking, each steak was allowed to equilibrate to room temperature (22°C) and 6 to 10 cores (1.27 cm in diameter) were removed from each steak parallel to the muscle fiber orientation. Each core was sheared once, perpendicular to the muscle fiber orientation, with a Warner-Bratzler shear machine (G-R Electric Manufacturing Co., Manhattan, KS), and peak shear force measurements were recorded and averaged to obtain a single shear force value for each steak.

Consumer Sensory Evaluation

A private marketing and economic research firm (Branson Research Associates, Bryan, TX), with extensive expertise in generating sample populations of consumers, was contracted to generate random phone listings for persons in the Denver, CO, metro area. These telephone listings were given to a telemarketing firm (Client Insight, Ft. Collins, CO) with expertise in conducting telephone surveys to recruit consumers for the untrained consumer panels. Consumers were contacted by telephone and prescreened to ensure that they were at least 18 yr of age and consumers of beef products. Sampling methods employed by the market and economic research firm targeted a sample population of consumers that was representative of the age, income, and ethnic background of the U.S. population. Consumers, selected according to criteria specified above and who were willing to participate in the study, were assigned to one of four testing locations used to conduct untrained consumer evaluation panels in the Denver Metro area (Denver, Lakewood, Arvada, or Littleton). A total of 25 consumer panel evaluation sessions were conducted that included a total of 489 consumers.

Paired steaks from each of the 50 carcasses per experimental treatment group were randomly assigned to one of the 25 consumer panel evaluation sessions. Within a session, paired steaks from 22 different carcasses were selected for sensory evaluation. In the randomization scheme, treatments were balanced within session (two carcass identification numbers representing each treatment). However, steaks from different ranches were assigned randomly to sessions. Steak identification numbers, as well as order of service to consumer panelists, were assigned randomly to each of the 20 consumers per session. Each consumer evaluated steak samples from each of the 11 treatment groups during each 60-min session.

Frozen steaks prepared for consumer panel evaluation were thawed at 2°C for 24 h and cooked for approximately 15 min on electric grills (model GGR64, Salton, Inc., Mt. Prospect, IL) that heated steaks from both sides simultaneously to a final internal temperature of 70°C. A Type K thermocouple (Omega Engineering Inc., Stamford, CT) was placed in the geometric center of each steak, and the internal temperature of each steak was monitored during cooking using a microprocessor thermometer (model HH21, Omega Engineering Inc., Stamford, CT). Steaks were cut into 1.3 × 1.3 × 2.5-cm portions, covered, and placed in a warming oven (49°C) until served to consumers. One steak of each pair of steak samples from each carcass identification number was prepared for serving during the first half of the session, whereas the other matched steak from each carcass was prepared for serving in the last half of the session to minimize any changes in sensory attributes associated with holding samples for longer periods of time in a warming oven.

Consumer panel evaluation procedures used for this study were approved by the Colorado State University Use of Humans in Research Committee. At each location, consumers were randomly seated at tables arranged in a circular order in a room containing standard fluorescent lighting. Instructions regarding the structure of the ballot and sampling procedures for the steak samples were provided verbally to the consumers in each session. Panelists were provided double-distilled, deionized water and salt-free saltine crackers, and were instructed to take a bite of cracker and a drink of water before evaluating each sample to cleanse their palate and to minimize sensory fatigue between samples.

Consumers rated each steak sample for like/dislike of tenderness, flavor, and juiciness using nine-point, end-anchored, hedonic scales, where 1 = like extremely and 9 = dislike extremely. Additionally, consumers were asked if they were satisfied (yes or no) with the overall eating quality of each sample.

Statistical Methods

Analyses of growth traits and carcass data were conducted using the least squares, mixed model procedure of SAS (SAS Inst. Inc., Cary, NC). In all analyses, individual animals were used as the experimental units. The statistical model for the steer growth traits included treatment as the independent fixed effect, ranch (a block effect), and ranch × treatment as random effects. For analysis of carcass traits, harvest date (date), date within ranch, and treatment × date within ranch were added to the ANOVA model as random effects because not all of the cattle were harvested on the same date. Because the design of this experiment specified feeding the steers to a common fat thickness (measured over the 12th rib), adjusted fat thickness was used as a covariate in the analyses of all carcass traits. All of the fixed and random variables included in the ANOVA model used to analyze carcass data also were included in the ANOVA model used to analyze shear force data. Additionally, aging period (14 and 21 d) was included as a fixed effect (repeated measure), aging period × date within ranch and aging period × ranch × treatment were included as random effects, and peak internal steak temperature served as a covariate for analysis of shear force data.

Treatment and location of the panel (location) were included as fixed effects in the model used to analyze the data generated from consumer panels. Date within ranch, treatment × ranch, treatment × date within ranch, steer identification number within treatment × date × ranch, panel session within location, and consumer within panel session × location were included as random effects in the ANOVA model used to analyze consumer panel sensory ratings.

Additional analyses for all traits were performed substituting number of implants administered during the lifetime of each steer (zero, two, three, four, or five) for the fixed treatment class variable to ascertain the effects of the number of implants administered on the respective traits analyzed in each model.

When F-tests were significant ($P < 0.05$), multiple comparisons of treatment means were performed using paired comparison t-tests. Frequency distributions of

USDA quality grades (Choice and Prime and upper two-thirds of Choice and Prime) and shear force values (above and below 4.5 kg) among control and treatment groups were compared using the χ^2 test of SAS (1998). If the overall χ^2 analysis was significant, Fisher's exact test of SAS was used to separate the percentages. Contrasts were partitioned in analysis of variance models to compare effects of implanting at branding, weaning, and backgrounding in mixed model analysis of SAS.

Results and Discussion

Carcass Quality Traits

Comparisons of mean marbling scores and USDA quality grade distributions for each treatment group are presented in Table 3. Carcasses of steers in the control group (Treatment 1) had higher ($P < 0.05$) marbling scores than did carcasses of steers in all other treatment groups. Steers in treatment 2, which were not implanted before the finishing phase, produced carcasses that had higher ($P < 0.05$) marbling scores when compared to steers in treatments 6, 7, and 11 (e.g., those that received some of the more aggressive lifetime implant strategies). Implanting steers at branding, weaning, or backgrounding prior to the finishing phase vs. not implanting at these production stages did not affect ($P > 0.05$) marbling scores (Table 4). Steers receiving only two implants produced carcasses with higher ($P < 0.05$) marbling scores than did steers receiving four or five implants (Table 5).

The percentage of carcasses grading Choice and Prime (range 56 to 82%) did not differ ($P = 0.15$) among treatments (Table 3). However, the frequency distribution of USDA quality grades within the Choice and Prime grades was shifted slightly as a result of the administration of some implant strategies. Within the control group, 54% of the steers produced carcasses that graded in the upper two-thirds of Choice or Prime, which was higher ($P < 0.05$) than the percentage of carcasses with the same grade classifications in treatments 3, 7, 9, and 11 (Table 3). Steers in treatment 2 produced a higher ($P < 0.05$) percentage of carcasses grading in the upper two-thirds of Choice or Prime than did steers subjected to treatment eleven (36 vs. 14%; Table 3). Implanting steers at branding, weaning, or backgrounding prior to the finishing phase vs. not implanting at these production stages did not affect ($P > 0.05$) the percentage of carcasses grading Choice and Prime (Table 4). The percentage of carcasses grading Choice and Prime was higher ($P < 0.05$) for nonimplanted steers than for steers implanted four or five times (Table 5). Similarly, the percentage of carcasses grading in the upper two-thirds of Choice or Prime was higher ($P < 0.05$) for nonimplanted steers than for steers implanted three, four, or five times (Table 5). Implanting steers five times decreased ($P < 0.05$) the percentage of carcasses grading in the upper two-thirds of Choice or Prime compared to implanting steers twice (Table 5).

Table 3. Least squares means of marbling scores of carcasses, USDA quality grade distribution of carcasses, and Warner-Bratzler shear force values (WBS) for 2.54-cm striploin steak samples cooked to 70°C stratified by lifetime implant strategy[a]

	Implant strategy[b]											
Trait	1	2	3	4	5	6	7	8	9	10	11	SEM
Marbling score[cd]	538^{w}	485^{x}	465^{xy}	454^{xyz}	464^{xyz}	439^{yz}	442^{yz}	457^{xyz}	460^{xyz}	453^{xyz}	430^{z}	25.4
Choice and Prime, %	82^{w}	70^{w}	74^{w}	64^{w}	68^{w}	56^{w}	60^{w}	62^{w}	72^{w}	64^{w}	60^{w}	—
Upper two-thirds Choice and Prime, %	54^{w}	36^{wx}	24^{xy}	26^{wxy}	26^{wxy}	26^{wxy}	22^{xy}	26^{wxy}	22^{xy}	28^{wxy}	14^{y}	—
Overall mean WBS, kg	3.54^{z}	3.95^{y}	4.46^{w}	4.19^{wxy}	4.19^{wxy}	4.15^{wxy}	4.12^{wxy}	4.05^{xy}	4.05^{xy}	4.14^{wxy}	4.38^{wx}	0.18
Steaks ≤ 4.5 kg (14-d), %	82^{w}	66^{wx}	44^{wx}	56^{wx}	54^{wx}	58^{wx}	50^{wx}	70^{wx}	62^{wx}	58^{wx}	38^{x}	—
Steaks ≤ 4.5 kg (21-d), %	94^{w}	88^{w}	76^{w}	74^{w}	76^{w}	80^{w}	78^{w}	84^{w}	82^{w}	80^{w}	64^{w}	—

[a]Repetitive measurements of peak shear force values, performed on adjacent steaks of striploin samples, after respective 14- and 21-d aging periods.
[b]Implant strategy with respect to products administered: 1 = no/no/no/no/no (control); 2 = no/no/no/Synovex-S/Revalor-S; 3 = no/no/Ralgro/Synovex-S/Revalor-S; 4 = no/no/Synovex-S/ Synovex-S/ Revalor-S; 5 = Synovex-C/no/ Synovex-S/no/ Revalor-S; 6 = no/ Ralgro/Synovex-S/ Synovex-S/Revalor-S; 7 = Synovex-C/no/ Ralgro/Synovex-S/Revalor-S; 8 = Synovex-C/no/ Synovex-S/ Synovex-S/Revalor-S; 9 = Synovex-C/ Ralgro/ Ralgro/ Synovex-S/ Revalor-S; 10 = Synovex-C/ Ralgro/ Synovex-S/ Synovex-S/Revalor-S; 11 = Synovex-C/ Ralgro/ Synovex-S/ Revalor-S/ Revalor-S. Synovex-C = 10 mg of estradiol benzoate, 100 mg of progesterone; Ralgro = 36 mg of zeranol; Synovex-S = 20 mg of estradiol benzoate, 200 mg of progesterone; Revalor-S = 24 mg of 17-β estradiol, 120 mg of trenbolone acetate.
[c]Adjusted to a common fat thickness
[d]300 = slight, 400 = small, 500 = modest.
[w,x,y,z]Means in the same row lacking a common superscript letter differ ($P < 0.05$).

Table 4. Probabilities of significance of contrasts for means of implant strategies differing by phase of production

Implanted at production phase[a]	Least squares means						*P* of contrasts		
	Branding		Weaning		Backgrounding		Branding	Weaning	Backgrounding
Trait[b]	No	Yes	No	Yes	No	Yes	No/Yes	No/Yes	No/Yes
Marbling[cd]	453	451	451	451	485	460	0.825	0.936	0.087
Choice and Prime, %	64.7	62.0	62.0	64.0	70.0	69.0	0.406	0.661	0.9241
Shear force, kg	4.26	4.10	4.12	4.11	3.95	4.33	0.104	0.958	0.016
WW, kg	189	194	—	—	—	—	0.164	—	—
BKW, kg	239	246	239	250	—	—	0.046	0.009	—
FLEW, kg	360	364	360	367	339	357	0.301	0.109	0.009
FW	583	578	576	586	563	581	0.366	0.056	0.027
ADG, WW to BKW	1.09	1.14	1.09	1.21	—	—	0.222	0.006	—
ADG, BKW to FLEW	1.39	1.37	1.37	1.37	1.21	1.39	0.289	0.723	0.001
ADG, FLEW to FW	1.48	1.42	1.44	1.43	1.42	1.49	0.001	0.533	0.297
ADG, WW to FW	1.43	1.39	1.40	1.42	1.33	1.43	0.020	0.216	0.001
HCW[c], kg	367	364	361	369	356	365	0.302	0.022	0.078
LMA[c], cm^2	84.8	83.5	83.5	84.8	82.8	84.1	0.196	0.179	0.241
YG[c]	3.24	3.25	3.25	3.26	3.27	3.25	0.973	0.984	0.814
Overall maturity[c]	A^{59}	A^{63}	A^{61}	A^{62}	A^{57}	A^{58}	0.014	0.303	0.375

[a]Lifetime implant strategies were identical for the two groups used in each contrast, except for implants administered at the specific production phase. See Table 2 for details on the contrasts.
[b]WW = weaning weight; BKW = backgrounding weight; FLEW = feedlot entry weight; FW = final live weight; ADG = average daily gain ($kg^{-1}·d^{-1}$); HCW = hot carcass weight; LMA = longissimus muscle area; YG = calculated USDA yield grade.
[c]Adjusted to a common fat thickness.
[d]300 = slight, 400 = small, 500 = modest.

In agreement with the results of the present study, several other studies have shown that the use of implants tends to decrease marbling scores and USDA quality grades (Bartle et al., 1992; Herscheler et al., 1995; Preston et al., 1995). Conversely, some studies have shown that the use of implants has little or no effect on marbling score or USDA quality grade (Gerken et al., 1995, Johnson et al., 1996; Rumsey et al., 1999).

Most previous studies documenting the effects of implant strategy on beef carcass quality have been limited to evaluations of a single implant or two successive implants administered during the finishing period. Only a few studies have compared the effects of implants administered in the suckling and growing phases of production on beef carcass quality. Mader et al. (1994) reported that marbling scores did not differ for steers that received a pre-weaning implant (Synovex-C) compared with steers that were not implanted prior to weaning. In another study, Mader (1994) compared steers receiving a Synovex-S implant in the growing phase with steers that were not implanted in the growing phase and observed no effect of implant treatment on marbling score. Pritchard et al. (2000) reported similar marbling scores for nonimplanted steers and steers

Table 5. Least squares means of implant strategies differing by number of implants administered

	Means by number of implants administered					
Trait[a]	0	2	3	4	5	SEM
Marbling[bc]	538^{x}	485^{y}	461^{yz}	447^{z}	447^{z}	24.1
Choice and Prime, %	82.0^{x}	70.0^{xy}	68.7^{xy}	59.3^{y}	65.3^{y}	—
Upper two-thirds Choice and Prime, %	54.0^{x}	36.0^{xy}	25.3^{yz}	24.7^{yz}	21.4^{z}	
Shear force, kg	3.54^{z}	3.97^{y}	4.27^{x}	4.12^{xy}	4.19^{xy}	0.15
Steaks ≤ 4.5 kg (14-d), %	82.0^{x}	66.0^{xy}	51.3^{y}	59.3^{y}	52.7^{y}	—
Steaks ≤ 4.5 kg (21-d), %	94.0^{x}	88.0^{xy}	75.3^{y}	80.7^{y}	75.3^{y}	—
FW, kg	523^{z}	564^{y}	580^{xy}	579^{xy}	582^{x}	5.93
HCW[b], kg	326^{z}	355^{y}	363^{xy}	364^{xy}	367^{x}	4.01
ADG, kg WW to FW	1.20^{z}	1.35^{y}	1.43^{x}	1.41^{x}	1.41^{x}	0.048
LMA[b], cm^2	74.8^{y}	83.2^{x}	83.2^{x}	84.5^{x}	84.5^{x}	1.01
Overall maturity[b]	A^{57y}	A^{55y}	A^{58y}	A^{62x}	A^{64x}	1.88

[a]FW = final live weight; HCW = hot carcass weight; WW = weaning weight; LMA = longissimus muscle area; ADG = average daily gain ($kg^{-1}·d^{-1}$).
[b]Adjusted to a common fat thickness.
[c]300 = slight, 400 = small, 500 = modest.
[x,y,z]Means in the same row that do not have a common superscript differ ($P < 0.05$).

receiving a low potency lifetime implant strategy, whereas marbling scores were higher for nonimplanted steers than for steers receiving intermediate- or high-potency lifetime implant treatments. Samber et al. (1996) reported that steers in a treatment group administered three implants in their lifetime produced carcasses with lower marbling scores and a lower percentage of Choice and Prime carcasses than did steers in a nonimplanted control group. In that study, similar marbling scores and percentage of carcasses grading USDA Choice or Prime were observed for steers in the nonimplanted treatment and steers in a treatment group administered two implants in their lifetime (Samber et al., 1996).

Shear Force

Least squares means for the repeated measurement of shear force obtained after 14 and 21 d of aging are reported in Table 3. Steaks obtained from steers in the control group had lower ($P < 0.05$) mean shear force values than steaks obtained from steers in all other treatment groups (Table 3). Steers assigned to treatment 2 (the most conservative lifetime implant protocol, other than the nonimplanted control) produced steaks with lower ($P < 0.05$) mean shear force values than steaks obtained from steers in treatments 3 and 11. Implanting at branding or weaning production phases did not affect ($P > 0.05$) shear force values; however, implanting at the backgrounding production phase increased ($P < 0.05$) mean shear force values (Table 4).

A Warner-Bratzler shear force value of 4.5 kg is commonly used as a maximal "threshold" level of consumer desirability for tenderness of beef top loin steaks (NCA, 1994). Using this threshold level, the percentage of steaks after a 14- or 21-d aging period with shear force values <4.5 kg produced from steers receiving three, four, or five implants was lower ($P < 0.05$) than the percentage of steaks produced from steers in the control group (Table 5). Postmortem aging time improved ($P < 0.05$) shear force values, with a 15.3% reduction in shear force values for steaks aged for 21 d compared to steaks aged only 14 d. The interaction of postmortem aging period and implant treatment group was not significant ($P = 0.99$), indicating that the response to aging for 14 and 21 d was similar for all treatment groups.

In a review, Morgan (1997) reported that the average shear force value of top loin steaks obtained from implanted cattle was approximately 0.5 kg greater than for steaks from carcasses of nonimplanted cattle and, regardless of aging time, steaks from carcasses of "aggressively" implanted cattle were tougher than steaks from nonimplanted or "conservatively" implanted cattle. Results of our study were consistent with other studies that have reported increased shear force values for steaks obtained from carcasses of implanted cattle (Samber et al., 1996; Foutz et al., 1997; Rumsey et al., 1999). In contrast, Gerken et al. (1995) and Pruneda et al. (1999) reported no difference in shear force values for steaks produced from implanted and nonimplanted cattle. Pritchard et al. (2000) reported higher shear force values for steaks obtained from steers administered a "high potency" lifetime implant strategy (e.g., Synovex-C; Revalor-G, Synovex-S, and Revalor-S) compared with steaks obtained from steers treated with a "low potency" lifetime implant protocol (e.g., four consecutive Ralgo implants). Other evidence suggests that shear force values are not affected by the aggressiveness of the lifetime implant regimen for calf-fed steers (Schoonmaker et al., 2001).

Table 6. Frequency distribution of consumer demographic information

Category	%
Gender	
Male	44.2
Female	55.8
Annual household income level	
<$10,000	4.6
$10,000 to 20,000	7.8
$20,000 to 30,000	10.3
$30,000 to 40,000	13.7
$40,000 to 50,000	14.1
$50,000 to 60,000	12.7
$60,000 to 70,000	7.0
$70,000 to 80,000	9.3
$80,000 to 90,000	5.9
>$90,000	14.6
Ethnic background	
African-American	10.8
American Indian	0.8
Asian or Pacific Islander	1.7
Hispanic	8.9
White	75.7
Other	2.1
Primary shopper of the household	
Yes	74.6
No	25.4
Number of times per week beef is consumed as a portion of an evening meal	
Never	0.2
1	10.3
2	31.4
3	33.5
4 or more times	24.6

Consumer Sensory Panels

Frequency distributions for consumer demographic attributes are reported by category as a percentage of the total sample population (Table 6). The majority of the consumer panelists were female (56%) and were the primary shopper within the household (75%). The average age of consumers was 46 yr, with a total range in age within the sample population of 18 to 84 yr. Of the incomes reported, the highest percentage of consumers reported having a total household income of between $40,000 and $49,000 per year, but incomes ranged from less than $10,000 to greater than $90,000 per year across panelists. A high percentage of consumers reported their ethnic background as Caucasian (76%), followed by African-American (11%) and Hispanic (8%). A very low percentage of the sample population reported an ethnicity of American Indian and Asian or Pacific Islander. Taste panel participants said they consumed beef as part of an evening meal two to three times per week. Because this sample population represented consumers from diverse age levels, income levels, and ethnic backgrounds, and included consumers categorized as "beef-eaters," the consumer demographic profile was deemed to be an acceptable population to test whether or not the repetitive use of implants influenced consumer perception of beef palatability attributes.

Consumer ratings for like/dislike of tenderness, flavor, and juiciness were influenced ($P < 0.05$) by treatment group (Table 7). Steaks from nonimplanted steers received more desirable ($P < 0.05$) ratings for tenderness like/dislike and juiciness like/dislike than steaks steers in all other treatment groups. Among treatment groups that received implants, steaks produced by steers in treatment 11 were rated less desirable ($P < 0.05$) for like/dislike of tenderness compared to steaks produced by steers in treatments 2, 7, and 9, and less desirable ($P < 0.05$) for like/dislike of juiciness and like/dislike of flavor compared to steaks produced by steers in treatment group 2. Steers in the control group produced steaks with more desirable ($P < 0.05$) consumer sensory ratings for like/dislike of flavor than did steers in all other treatment groups, except for treatment group 2. For steers receiving implants, the number of implants administered had no effect ($P > 0.05$) on consumer ratings for like/dislike of tenderness, flavor, or juiciness (Table 8). Moreover, administering implants at branding, weaning, or backgrounding did not affect ($P > 0.05$) consumer ratings of like/dislike of tenderness, flavor, or juiciness (data not shown).

On average, 60 to 74% of consumers were satisfied with the overall eating quality of steaks from the various experimental treatment groups (Table 7). The percentage of consumers satisfied with overall eating quality of steaks was not influenced ($P = 0.22$) by treatment when all 11 treatment groups were compared. However, when grouped by number of implants, implant protocol affected ($P < 0.05$) the percentage of satisfied consumers with respect to overall steak eating quality. Administering implants two, three, four, or five times decreased ($P < 0.05$) the percentage of satisfied consumers compared with a lifetime implant protocol that used no implants (Table 8). Implanting steers at branding, weaning, and backgrounding production phases had no effect ($P > 0.05$) on the percentage of satisfied consumers with respect to overall eating quality of the resulting steaks (data not shown).

Only a limited amount of information is available concerning the effects of implant strategies on consumer sensory evaluations of beef palatability traits. Roeber et al. (2000a) reported decreased consumer tenderness ratings of beef strip loin steaks derived from

Table 7. Least squares means for consumer sensory responses by experimental treatment group

Consumer sensory response	Model $P > F$	SEM	Implant strategy[a] 1	2	3	4	5	6	7	8	9	10	11
Tenderness[b]	0.009	0.21	3.15^{z}	3.79^{y}	4.05^{xy}	4.00^{xy}	3.87^{xy}	3.91^{xy}	3.78^{y}	3.96^{xy}	3.71^{y}	3.80^{xy}	4.25^{x}
Flavor[b]	0.037	0.12	3.34^{z}	3.62^{yz}	3.81^{xy}	3.76^{xy}	3.71^{xy}	3.73^{xy}	3.74^{xy}	3.83^{xy}	3.70^{xy}	3.82^{xy}	3.92^{x}
Juiciness[b]	0.030	0.17	3.54^{z}	3.91^{y}	4.17^{xy}	4.11^{xy}	4.00^{xy}	4.12^{xy}	4.02^{xy}	4.17^{xy}	4.06^{xy}	4.02^{xy}	4.30^{x}
Satisfaction with overall eating quality, %	0.222	3.90	73.6	65.0	61.1	63.7	65.1	61.4	66.9	62.1	67.3	62.5	60.4

[a]Implant strategy with respect to products administered: 1 = no/no/no/no/no (control); 2 = no/no/no/Synovex-S/Revalor-S; 3 = no/no/Ralgro/Synovex-S/Revalor-S; 4 = no/no/Synovex-S/ Synovex-S/ Revalor-S; 5 = Synovex-C/no/ Synovex-S/no/ Revalor-S; 6 = no/ Ralgro/Synovex-S/ Synovex-S/Revalor-S; 7 = Synovex-C/no/ Ralgro/Synovex-S/Revalor-S; 8 = Synovex-C/no/ Synovex-S/ Synovex-S/Revalor-S; 9 = Synovex-C/ Ralgro/ Ralgro/ Synovex-S/ Revalor-S; 10 = Synovex-C/ Ralgro/ Synovex-S/ Synovex-S/Revalor-S; 11 = Synovex-C/ Ralgro/ Synovex-S/ Revalor-S/ Revalor-S. Synovex-C = 10 mg of estradiol benzoate, 100 mg of progesterone; Ralgro = 36 mg of zeranol; Synovex-S = 20 mg of estradiol benzoate, 200 mg of progesterone; Revalor-S = 24 mg of 17-β estradiol, 120 mg of trenbolone acetate.

[b]Tenderness, flavor, and juiciness like to dislike rating by consumers where: 1 = liked extremely and 9 = disliked extremely.

[x,y,z]Means in the same row that do not have a common superscript differ ($P < 0.05$).

Table 8. Least squares means for consumer sensory ratings of steaks from implant strategies differing by number of implants administered

Consumer sensory response	Means by number of implants administered					SEM
	0	2	3	4	5	
Tenderness[b]	3.15[z]	3.79[y]	3.97[y]	3.88[y]	3.93[y]	0.157
Flavor[a]	3.34[z]	3.62[y]	3.76[y]	3.77[y]	3.82[y]	0.088
Juiciness[a]	3.54[z]	3.91[y]	4.10[y]	4.10[y]	4.13[y]	0.116
Satisfaction with overall eating quality, %	73.6[y]	65.0[z]	63.2[z]	63.5[z]	63.5[z]	3.075

[a]Tenderness, flavor, and juiciness like to dislike rating by consumers where: 1 = liked extremely and 9 = disliked extremely.

[y,z]Means in the same row that do not have a common superscript differ ($P < 0.05$).

implanted steers (in six out of seven finishing implant protocols) when compared to steaks of nonimplanted cattle. The 1995 Beef Consumer Satisfaction Report (NLSMB, 1995) indicated there was a tendency for consumer ratings of overall beef desirability to be reduced for beef from cattle administered two successive androgen-containing implants when compared to beef from cattle administered a single implant, two consecutive estrogenic implants, or an estrogenic implant followed by a estrogenic + androgenic implant. Conversely, Roeber et al. (2000a) reported that consumer ratings of like/dislike of flavor and juiciness and overall like/dislike were not influenced by a combination estrogenic + androgenic implant.

Research has shown that consumer sensory responses for overall tenderness and overall like for strip loin steaks may be influenced by USDA quality grade (NLSMB, 1995). In this study, when all steak consumer panel ratings were adjusted to reflect a common carcass marbling score, no differences ($P > 0.05$) in consumer ratings (between treatment or classification by number of implants) for like/dislike of tenderness, flavor, or juiciness, or for the percentage of consumers satisfied with overall eating quality of steaks were observed (data not shown).

Growth and Carcass Traits

Contrasts comparing the effects of implanting at different phases of production on growth and carcass traits are presented in Table 4. Prefinishing implants generally increase the growth rate of steers during the production phase immediately following administration of these implants (Selk, 1994; Duckett et al., 1997; Kuhl, 1997). The net effect on the overall lifetime growth rate of steers for each implant administered throughout a steer's lifetime can be dependent on various factors, such as the animal's age, weight, production rate, and previous and subsequent implant treatment (Mader, 1994; Kuhl, 1997; Mader et al., 1997). In this study, implanting steers at branding did not affect ($P = 0.16$) weaning weight. Steers administered implants at branding and/or weaning were heavier ($P < 0.05$) at the initiation of the backgrounding phase compared with steers not implanted at these production phases. Implants administered at branding or weaning did not influence ($P > 0.05$) feedlot entry weights. Implants administered at backgrounding increased ($P < 0.05$) feedlot entry weights and the increase in weight was maintained throughout the remainder of the feeding period, resulting in increased ($P < 0.05$) final live weights for steers that received implants at backgrounding compared with those that did not.

Final live weights of implanted steers were between 7.7 to 12.5% heavier ($P < 0.05$), and ADG (weaning to harvest) were 11.8 to 20.5% higher ($P < 0.05$), than those for control steers (Table 9). Implants administered at branding did not influence ($P = 0.37$) final live weights, and were actually associated with decreased ($P < 0.05$) postweaning weight gains. These results were consistent with those of Mader et al. (1985; 1994) and Simms et al. (1988), who reported no influence in lifetime weight gains of implanting steers with estrogenic compounds during the suckling phase, provided that two or three additional implants were administered at regular intervals during the subsequent growing and finishing phases of production.

Implants administered at weaning did not influence ($P = 0.22$) postweaning ADG, but tended ($P = 0.056$) to increase final live weights of steers (Table 4). Backgrounding implants increased ($P < 0.05$) postweaning ADG and final live weights of steers (Table 4). The most distinct improvement in growth rate for implanted steers was observed during the finishing period (feedlot entry to harvest) when ADG was increased ($P < 0.05$) 20.2 to 34% compared with ADG for control steers (Table 9). Postweaning rates of gain were higher ($P < 0.05$) and final live weights were heavier ($P < 0.05$) for steers implanted three, four, or five times compared to steers implanted twice (Table 5). No differences ($P > 0.05$) in final live weights or postweaning ADG were observed for animals that received three, four, or five implants (Table 5).

Comparisons of treatment least squares means for harvest and carcass traits (adjusted to the mean external fat thickness for all steers) are presented in Table 9. Implant treatment had no effect ($P = 0.15$) on dressing percentage. Mean hot carcass weights for implanted steers were between 8.9 to 13.8% heavier ($P < 0.05$) than those for control steers. Branding implants had

Table 9. Least squares means for growth and carcass traits

Trait	Implant strategy[a]											SEM
	1	2	3	4	5	6	7	8	9	10	11	
WW, kg[b]	193^{v}	190^{v}	190^{v}	187^{v}	188^{v}	190^{v}	189^{v}	194^{v}	194^{v}	198^{v}	190^{v}	13.8
FEW, kg	346^{xy}	339^{y}	357^{vwx}	357^{vwx}	355^{wx}	365^{vw}	358^{vwx}	364^{vx}	366^{vw}	371^{v}	362^{vw}	11.4
FW, kg	523^{x}	564^{w}	584^{v}	578^{vw}	578^{vw}	588^{v}	575^{vw}	573^{vw}	581^{vw}	588^{v}	580^{vw}	6.99
ADG, kg FEW to FW	1.12^{x}	1.42^{vw}	1.50^{vw}	1.48^{vw}	1.50^{v}	1.47^{vw}	1.42^{vw}	1.42^{vw}	1.43^{vw}	1.41^{vw}	1.35^{w}	0.043
DOF, finishing phase	146^{v}	147^{v}	144^{v}	143^{v}	148^{v}	145^{v}	147^{v}	144^{v}	144^{v}	146^{v}	148^{v}	10.7
ADG, kg WW to FW	1.20^{y}	1.35^{x}	1.43^{vw}	1.43^{vw}	1.40^{vwx}	1.44^{v}	1.39^{vwx}	1.38^{wx}	1.41^{vw}	1.41^{vw}	1.39^{vwx}	0.052
HCW^{cd}	326^{z}	355^{y}	367^{vwx}	363^{vwxy}	359^{wxy}	371^{v}	361^{vwxy}	358^{xy}	364^{vwxy}	370^{vw}	366^{vwxy}	4.86
Dressing^{c} %	62.4^{v}	63.0^{v}	62.8^{v}	62.9^{v}	62.2^{v}	63.1^{v}	62.8^{v}	62.5^{v}	62.8^{v}	63.0^{v}	63.2^{v}	0.270
FT, cm	1.63^{v}	1.50^{v}	1.52^{v}	1.52^{v}	1.47^{v}	1.47^{v}	1.52^{v}	1.47^{v}	1.55^{v}	1.50^{v}	1.55^{v}	0.079
LMA^{c}, cm^{2}	75.6^{z}	83.0^{xy}	85.1^{vwx}	84.1^{vwxy}	81.3^{y}	86.4^{v}	84.9^{vwx}	82.5^{xy}	83.5^{wxy}	84.8^{vwx}	85.9^{vw}	1.21
KPH^{c} %	2.52^{v}	2.29^{w}	2.16^{wxy}	2.13^{xy}	2.26^{wx}	2.18^{wxy}	2.15^{wxy}	2.17^{wxy}	2.14^{xy}	2.07^{y}	2.15^{wxy}	0.058
YG^{c}	3.43^{v}	3.27^{wv}	3.24^{x}	3.25^{x}	3.38^{vw}	3.22^{x}	3.19^{x}	3.30^{wx}	3.28^{wx}	3.27^{wx}	3.19^{x}	0.058

[a]Implant strategy with respect to products administered: 1 = no/no/no/no/no (control); 2 = no/no/no/Synovex-S/Revalor-S; 3 = no/no/Ralgro/Synovex-S/Revalor-S; 4 = no/no/Synovex-S/ Synovex-S/ Revalor-S; 5 = Synovex-C/no/ Synovex-S/no/ Revalor-S; 6 = no/ Ralgro/Synovex-S/ Synovex-S/Revalor-S; 7 = Synovex-C/no/ Ralgro/Synovex-S/Revalor-S; 8 = Synovex-C/no/ Synovex-S/ Synovex-S/Revalor-S; 9 = Synovex-C/ Ralgro/ Ralgro/ Synovex-S/ Revalor-S; 10 = Synovex-C/ Ralgro/ Synovex-S/ Synovex-S/Revalor-S; 11 = Synovex-C/ Ralgro/ Synovex-S/ Revalor-S/ Revalor-S. Synovex-C = 10 mg of estradiol benzoate, 100 mg of progesterone; Ralgro = 36 mg of zeranol; Synovex-S = 20 mg of estradiol benzoate, 200 mg of progesterone; Revalor-S = 24 mg of 17-β estradiol, 120 mg of trenbolone acetate.

[b]WW = weaning weight; FEW = feedlot entry weight; FW = final live weight; ADG = average daily gain ($kg^{-1} \cdot d^{-1}$); DOF = d on feed; HCW, hot carcass weight; FT = adjusted fat thickness; LMA = longissimus muscle area; KPH = estimated kidney, pelvic, and heart fat; YG = calculated USDA yield grade.

[c]Adjusted to a common fat thickness.

[d]Unadjusted hot carcass weights were: 325, 356, 367, 363, 360, 372, 361, 359, 363, 371, and 366 for treatments 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11, respectively.

[v,w,x,y,z]Means in the same row that do not have a common superscript differ ($P < 0.05$).

no effect ($P = 0.30$) on hot carcass weight; however, weaning implants increased ($P < 0.05$) and backgrounding implants tended ($P = 0.078$) to increase hot carcass weights (Table 4). Administering five implants throughout a steer's lifetime increased ($P < 0.05$) hot carcass weight compared to the use of only two implants (Table 5).

Implanting steers increased the mean ($P < 0.05$) longissimus dorsi area, measured at the 12th rib (**LMA**), of steers in all treatment groups compared to the mean for steers in the control group. Numerous studies have reported that the use of implants, administered in the finishing phase, increases LMA (Anderson et al., 1991; Samber et al., 1996; Roeber et al., 2000a). In this study, implanting steers at any production phase prior to feedlot entry did not affect ($P > 0.05$) LMA (Table 4).

In agreement with results of the present study (Table 9), several previous studies have shown little effect of implant treatment on external fat thickness (Samber et al., 1996; Foutz et al., 1997; Roeber et al., 2000a). Implant treatment affected the estimated percentage of kidney, pelvic, and heart fat since steer carcasses in the control group had higher ($P < 0.05$) mean values for this trait than did steer carcasses in all other treatment groups.

Carcasses of steers in the nonimplanted control group had higher ($P < 0.05$) mean values for calculated USDA yield grade than did carcasses of steers in nine out of the 10 implanted treatment groups. Additionally, the numerical percentage of carcasses assigned yield grades of 1and 2 was lowest for the control group (16%) and highest for treatment six (40%), but these values did not differ statistically ($P > 0.05$) when tested via the χ^2 procedure. Implanting steers at branding, weaning, and backgrounding production phases had no effect ($P > 0.05$) on calculated USDA yield grades of carcasses (Table 4).

Steers in treatment 11 produced carcasses exhibiting advanced overall maturity scores, differing ($P < 0.05$) from all other treatments except groups 8 and 10 (data not shown). Implanting at branding vs. not implanting at this production phase increased ($P < 0.05$) overall maturity scores (Table 4). Steers implanted four or five times produced carcasses exhibiting more advanced ($P < 0.05$) overall maturity scores than steers implanted zero, two, or three times (Table 5). However, 98.9% of the carcasses in this study were classified as A-maturity, so the practical significance of observed differences in maturity scores was considered to be minor.

Previous research has linked the use of combination (androgen and estrogen) implants in steers at the time of reimplantation in the feedlot with an increased incidence of carcasses exhibiting "dark-cutting" beef characteristics (Scanga et al., 1998). In the present study, only 0.7% of the carcasses exhibited the "dark-cutting" condition, and there were no apparent differences among treatments in the incidence of "dark-cutting" carcasses (data not shown).

Implications

Results of this study suggest that lifetime implant protocols affected both the eating quality and tenderness of beef and emphasize the importance of choosing implant programs based on specific marketing targets for cattle. Producers retaining ownership of steer calves destined for marketing on a "quality-oriented," value-based grid, may choose not to implant cattle until backgrounding or feedlot entry in order to minimize the risk of detrimental effects on beef quality associated with "aggressive" lifetime implant strategies. The effects of lifetime implant protocols on beef acceptability may be of particular interest to vertically coordinated branded beef programs interested in maximizing quality, consistency, and tenderness of their beef products.

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