Effect of nursing-calf implant timing on growth performance and carcass characteristics¹

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ABSTRACT: The objective of this study was to compare pre- and postweaning growth performance, carcass characteristics, and meat quality attributes of calves that did not receive an implant or were implanted early or late in the nursing period. Crossbred steer calves ($n = 135$) were stratified by birth date and birth weight and randomly assigned to the following implant treatments: control (CON; no preweaning implant), 58 d (EARLY; 36 mg zeranol, administered at an average of 58 ± 13 d of age), and 121 d (LATE; 36 mg zeranol, administered at an average 121 ± 13 d of age). After weaning, steers were blocked by initial feed yard BW to 15 pens (5 pens/treatment and 9 steers/pen). All steers were implanted on d 21 after arrival at the feed yard and again on d 108 of finishing. Steer BW and ultrasound assessment of rib eye area (uREA), rib fat thickness (uRFT), and percent intramuscular fat (uIMF) were collected when implants were administered, at weaning, and on harvest day. Carcass measurements included HCW, rib eye area (REA), 12th-rib fat thickness (FT), and marbling score. Objective color (L^* , a^* , and b^*) was recorded, and a 3.8-cm strip loin section was removed from both sides of each carcass and portioned into 2.54-cm steaks that were aged for 3 or 14 d

for analysis of cook loss and Warner–Bratzler shear force (WBSF). The remaining portion of each sample was used for analysis of moisture and crude fat. Steer BW, ADG, and G:F did not differ among treatments ($P > 0.05$). Steers implanted in the EARLY treatment had a greater ($P < 0.05$) cumulative DMI than CON but were not different from steers implanted in the LATE treatment. Ultrasound REA and uRFT (averaged across all collection days) did not differ ($P > 0.05$); however, steers on the CON treatment had a greater ($P \leq 0.05$) percent uIMF than EARLY implanted steers, whereas steers receiving the LATE implant were intermediate and not different from the other treatments. Hot carcass weight, REA, FT, USDA yield grade, marbling score, and objective color did not differ ($P > 0.05$) among treatments. The proportion of steers in each USDA yield and quality grade was similar ($P > 0.05$) among treatments, and no differences were detected for total carcass value or price per 45.4 kg (hundredweight; $P > 0.05$). Treatment did not influence ($P > 0.05$) percent cook loss, crude fat, moisture, or WBSF. In conclusion, administering a nursing implant, regardless of timing, did not influence live performance, carcass characteristics, or meat quality of steers fed in this study.

Key words: beef, feedlot performance, implant, meat quality, nursing calf, preweaning

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INTRODUCTION

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Anabolic implants are one of several growth-enhancing technologies available to beef producers. Implants work in conjunction with circulating hormones to increase protein deposition, enhancing both the rate and efficiency of muscle growth (Dayton and White, 2014). Consequently, implants are routinely administered to cattle as a response to

market incentives to increase growth rate and decrease production costs (Roerber et al., 2000).

In general, implants are primarily used in the postweaning phases of production, which may not maximize profitability or lean beef production for the entire beef system. Duckett and Andrae (2001) suggested that implanting nursing and/or stocker cattle has minimal negative effects on response to additional postweaning implants. Therefore, successive, lifetime implants should result in additive gains. In the cow-calf sector, implants are available for nursing calves and research has demonstrated that implants effectively increase ADG of calves during the suckling phase by 5 to 6% compared with nonimplanted calves (Duckett and Andrae, 2001). However, some research indicates that repetitive use of implants may have negative impacts on beef carcass quality and tenderness (Platter et al., 2003; Scheffler et al., 2003).

Although previous research has demonstrated that the type of implant and timing of administration can influence growth response and carcass characteristics during the stocker and feedlot phase (Paisley et al., 1999; Roerber et al., 2000; Duckett and Pratt, 2014), efforts focused on the timing of administering implants to nursing calves and the subsequent effects on feedlot performance and carcass quality are limited. Therefore, the hypothesis that implanting later in the nursing period would improve growth promotion without negatively influencing carcass quality was tested. The objective of this study was to compare pre- and postweaning performance and carcass characteristics among calves that did not receive an implant (control) or were implanted at approximately 60 d of age or at approximately 120 d of age.

MATERIALS AND METHODS

Animals

Cow-calf producers in the northern plains generally administer implants to nursing calves during occasions that coincide with other cattle working events, such as branding, when the calves are approximately 60 d of age. However, with advances in growth genetics and variability of grazing resources, delaying the administration of preweaning implants to coincide with preweaning vaccinations, when calves are approximately 120 d of age, was investigated. The South Dakota State University (SDSU) Animal Care and Use Committee approved all animal care and experimental protocols (approval number 14-083E). One hundred thirty-five Angus × Simmental crossbred male calves raised from a common herd were used for this study. Calves were located at the SDSU Antelope Range and Livestock Research Station near Buffalo, SD. Individual calves were stratified by birth date and birth BW and randomly assigned within

strata to 1 of 3 treatments: control (**CON**; no preweaning implant), 58 d (**EARLY**; 36 mg zeranol; Ralgro [Merck Animal Health, Madison, NJ] at branding; administered at an average of 58 ± 13 d of age), and 121 d (**LATE**; 36 mg zeranol in mid August; administered at an average of 121 ± 13 d of age). Beef Quality Assurance protocols for proper implant placement and equipment sanitation were used throughout the course of the study (BQA, 2010). Implants were administered subcutaneously in the middle third of the ear by a single technician on each day of administration. Implant needles were changed as needed to remain effective and disinfected after each use with a sponge soaked in 2% chlorhexidine solution.

Preweaning Management

Cow-calf pairs grazed native mixed-grass pastures throughout the preweaning period. Pastures were typical of northern mixed prairie. Common grass species included western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Nassella viridula*), needle-and-thread (*Hesperostipa comata*), blue grama (*Bouteloua gracilis*), buffalograss (*Bouteloua dactyloides*), little bluestem (*Schizachyrium scoparium*), and prairie sandreed (*Calamovilfa longifolia*). Monthly actual and average precipitation and temperature data are presented in Fig. 1. Pastures were stocked at 1.3 animal unit month/ha, which is a slightly lower stocking rate than the long-term average of 1.5 animal unit month/ha used at the SDSU Antelope Range and Livestock Research Station. Because precipitation was above average, abundant forage was available to the cattle. This should have allowed cows and calves to select a high-quality diet that would support the growth potential of the implant. The average adjusted 205-d weight of steer calves at the SDSU Antelope Range and Livestock Research Station from 2010 to 2015 was 266 ± 10 kg. The average adjusted 205-d weight of steers in this study period (2014) was 285 kg, further demonstrating that the forage growing conditions during this study period could support above average growth potential provided by an implant.

At study initiation on June 9, 2014, all steers were branded and individually weighed without shrink using a hydraulic squeeze chute with load cells mounted under the chute (Weigh-Tronix model 1015; Avery Weigh-Tronix, Fairmont, MN) and were administered a clostridial vaccine (UltraBac 7; Zoetis, Inc., Florham Park, NJ). Steers were also ultrasounded (Aloka SSD-500V real-time ultrasound machine; Hitachi Aloka Medical, Ltd., Tokyo, Japan) for ultrasound assessment of rib eye area (**uREA**), rib fat thickness (**uRFT**), and percent intramuscular fat (**uIMF**) at study initiation. While in the chute for these procedures, the **EARLY** treatment was implanted. On August 11, all steers were weighed

Figure 1. Monthly total precipitation and average temperature during the study year (2014, shown in bars), and monthly normal precipitation and temperature (1981–2010 long-term average, shown in dashed lines) at the South Dakota State University Antelope Range and Livestock Research Station (near Buffalo, SD). Information obtained from South Dakota State University State Climatology Office (Brookings, SD).

without shrink; ultrasounded; administered an infectious bovine rhinotracheitis, parainfluenza-3, bovine viral diarrhoea virus types 1 and 2, and bovine respiratory syncytial virus modified live virus vaccine (Vista 5; Merck Animal Health); vaccinated with a *Clostridium chauvoei*, *Clostridium septicum*, *Clostridium novyi*, *Clostridium sordellii*, and *Clostridium perfringens* types C and D, *Haemophilus somnus* bacterin-toxoid (Vision 7 Somnus with spur; Merck Animal Health); and administered a *Mannheimia haemolytica* type A1 bacterin-toxoid (One Shot; Zoetis, Inc.). While in the chute for these procedures, the LATE treatment steers were implanted.

Feedlot Management

All steers were weaned on October 27, 2014. At weaning, all steers were weighed, revaccinated with Vista 5 SQ and Vision 7 Somnus with Spur, administered Dectomax Pour-On Solution (Zoetis, Inc.), ultrasounded, and then shipped approximately 523 km to the University of Nebraska-Lincoln Panhandle Research and Extension Center in Scottsbluff, NE. Steers were blocked by initial feed yard BW into 15 pens (5 pens/treatment and 9 steers/pen).

Steers were appropriately managed and fed to maintain health and performance to an industry average compositional endpoint. Feed bunks were assessed at

Table 1. Composition of finishing diet (% of DM) fed to steers

Item	Composition
Ingredient composition	
Dry-rolled corn	61
Wet distiller's grains with solubles	25
Alfalfa hay	8
Liquid supplement ¹	6
Nutrient composition	
NEm, Mcal/kg	2.00
NEg, Mcal/kg	1.37
Starch	52.18
NDF	15.23
CP	13.11
Fat	3.04
Ca	0.67
K	0.59
P	0.33
Mg	0.16
S	0.15

¹Liquid supplement contained 0.6% urea and 1.6% Ca and was formulated to provide a dietary DM inclusion of 0.3% salt, 60 mg Fe/kg, 40 mg Mg/kg, 25 mg Mn/kg, 10 mg Cu/kg, 1 mg I/kg I, 0.15 mg Se/kg, 1.5 IU vitamin A/g, 0.15 IU vitamin D/g, 8.81 IU vitamin E/kg. Diet was formulated to provide 360 mg Rumensin (Elanco Animal Health, Greenfield, IN) per steer daily and 90 mg Tylan (Elanco Animal Health) per steer daily.

approximately 0700 h and managed for trace (≤ 0.2 kg) amounts of feed remaining in the bunk each morning at time of feeding. Feed was delivered with a truck-mounted mixer and delivery unit (Roto-Mix model 274; Roto-Mix, LLC, Dodge City, KS; scale readability ± 0.91 kg) each morning at 0800 h. Steers were placed on a high-forage receiving ration containing a mixture of ground wheat straw, ground alfalfa hay, corn silage, wet distiller's grains with solubles (Bridgeport Ethanol, LLC, Bridgeport, NE; 31.1% CP, 29.8% NDF, and 7.4% fat), and dry-rolled corn for 16 d (October 28 to November 12). Following the receiving period, steers received 6 concentrate-adaptation diets from November 13 to December 17 for adaptation to a high-concentrate diet. From December 18 to harvest, steers received a finishing ration that contained a mixture of alfalfa, wet distiller's grains with solubles, dry-rolled corn, and a supplement containing urea, minerals, vitamins, Rumensin (360 mg; Elanco Animal Health, Greenfield, IN), and Tylan (90 mg; Elanco Animal Health; Table 1). Diets were formulated to meet MP requirements published by the NRC (1996). Ingredient and diet samples were collected weekly and dried in a 60°C forced air oven for 48 h to determine the DM of the samples (Cunniff, 1997; method 930.15). Composited ingredient samples were sent to a commercial laboratory (Servi-Tech Laboratories, Hastings, NE) and analyzed for CP (Horwitz, 2000; method 990.03); NDF (ANKOM,

2006); ether extract (Horwitz and Latimer, 2006; method 2003.6); Ca, P, and S (Mills and Jones, 1996); and total starch (Horwitz, 2000; method 996.11) content.

Individual BW were recorded using a hydraulic squeeze chute with load cells mounted on the chute (Silencer; Moly Manufacturing Inc., Lorraine, KS; scale readability ± 0.45 kg) on November 17 and 18 and averaged to obtain the initial feed yard BW. All steers were ultrasounded and implanted with Revalor-IS (80 mg trenbolone acetate and 16 mg estradiol; Merck Animal Health) on November 17. All steers were ultrasounded and implanted with Revalor-200 (200 mg trenbolone acetate and 20 mg estradiol; Merck Animal Health) on February 12. Steers in the heaviest 3 blocks began receiving ractopamine hydrochloride (300 mg ractopamine hydrochloride $\cdot$ steer⁻¹ $\cdot$ d⁻¹; Optaflexx 45; Elanco Animal Health) in their ration on April 1 for 35 d. These steers were ultrasounded, weighed to establish final BW, and shipped approximately 195 km to Cargill Meat Solutions in Ft. Morgan, CO, on the morning of May 6. The remaining 2 blocks were administered ractopamine hydrochloride for 35 d beginning April 22 and were individually ultrasounded, weighed, and sent to the same beef processing facility on the morning of May 27. A total of 132 steers were shipped to the beef processing facility. Three steers (1 from each treatment) were removed from the study or died due to reasons unrelated to study treatments. One steer (LATE treatment) was removed from the experiment prior to harvest due to chronic bloat, 1 steer (EARLY treatment) died from unknown causes, and 1 steer (CON treatment) died of congestive heart failure. At the plant, 1 steer (LATE treatment) was condemned due to right heart failure. Final live BW was determined as HCW divided by 0.625 (assumed dressing percentage) to remove variability due to gastrointestinal fill.

Carcass Evaluation and Sample Collection

Cattle were individually tracked through slaughter, and HCW was recorded for 131 carcasses. Following carcass chilling (approximately 24 h), carcass measurements were determined by trained university personnel. Rib eye area (REA), 12th-rib fat thickness (FT), and estimated percentage of KPH were used to calculate USDA yield grade of each carcass, and marbling score and carcass maturity measures were used to determine the USDA quality grade of each carcass. A 3.81-cm section of strip loin was removed from both sides of each carcass immediately posterior to the 12th/13th rib separation. All sections were transported under refrigeration (2.2°C) to the SDSU Meat Laboratory (Brookings, SD). A 2.54-cm steak was fabricated from the anterior portion of each section. The steak from the right side was al-

lowed to bloom for 30-min evaluation of objective color (L^* , a^* , and b^*) using a Minolta colorimeter (model CR-310; Minolta Corp., Ramsey, NJ; 50 mm diameter measuring space and D65 illuminant). Steaks were then aged for either 3 or 14 d postmortem and used for Warner-Bratzler shear force (WBSF) analysis. The remaining posterior slice from the left side of each carcass was aged for 3 d and used to determine crude fat percentage. Once vacuum sealed, steaks were immediately stored in the absence of light at 2.2 to 3.8°C for the specified aging period. After completion of the designated aging period, steaks were frozen (-20°C) for later evaluation of tenderness and crude fat percentage.

Tenderness and Cook Loss Evaluation

Steaks designated for WBSF determination were thawed for 24 h at 3.8°C and then cooked on an electric clamshell grill (George Foreman 9 Serving Classic Plate Grill, model GR2144P; Spectrum Brands, Middleton, WI) to 71°C. Prior to cooking, the raw weight of each steak was recorded in grams. Peak internal cooked temperature measurements were recorded for each steak using a hand-held thermometer (model 35140; Cooper-Atkins Corp., Middlefield, CT). Steaks were allowed to rest after cooking, and cook loss was recorded as a percentage of the raw weight using the following equation: $[(\text{raw weight} - \text{cooked weight}) / \text{raw weight}] \times 100$. Cooked steaks were cooled for 24 h at 3.8°C before 6 to 8 cores (1.27 cm in diameter) were removed parallel to the muscle fiber orientation (AMSA, 2015). A single peak shear force measurement was obtained for each core using a Warner-Bratzler shear machine (G-R Electric Manufacturing Co., Manhattan, KS). Measurements of the peak shear force were recorded and averaged to obtain a single shear force value for each steak.

Ether Extractable Fat Percentage

Steaks were thawed slightly, and external fat, epimysial connective tissue, and additional muscles were trimmed from the LM, as outlined by Blumer et al. (1962). Slices (1 cm) of trimmed LM were minced, immersed in liquid nitrogen, and powdered using a Waring commercial blender (model 51BL32; Waring Laboratory Division, Lancaster, PA). Powdered samples were stored at -20°C in plastic bags (Whirlpack; Nasco, Fort Atkinson, WI). Prior to analysis, duplicate powdered samples (5 g) were weighed into tins, covered with filter papers, and dried in an oven at 101°C for 24 h. Dried samples were then placed into desiccators for 1 h prior to obtaining the nonextracted weight, which was used to calculate percent moisture. Samples were then extracted according to the AOAC International

Table 2. Least squares mean performance responses and ultrasound-measured composition (average across all periodic measurements) to timing of nursing implant

Variable ¹	Treatment ²			SEM	P-value ³
	CON	EARLY	LATE		
BW, kg	352	356	356	1.96	0.717
ADG, kg	1.72	1.74	1.66	0.009	0.314
Finishing DMI, kg	9.88 ^b	10.28 ^a	10.10 ^{ab}	0.119	0.043
G:F, kg/kg	0.176	0.171	0.167	0.0068	0.421
uREA, cm ²	52.68	52.98	52.88	0.919	0.958
uRFT, cm	0.66	0.64	0.66	0.025	0.896
uIMF, %	4.02 ^a	3.81 ^b	3.96 ^{ab}	0.083	0.034

^{a,b}Least squares means within a row with different superscripts differ ($P \leq 0.05$).

¹Initial calf BW used as a covariate for BW, ADG, DMI, and G:F. Initial ultrasound scan of rib eye area, 12th-rib fat thickness, and percent intramuscular fat was used as a covariate for ultrasound assessment of rib eye area (uREA), rib fat thickness (uRFT), and percent intramuscular fat (uIMF).

²Treatments: CON = control (no calf implant); EARLY = 36 mg zeranol, administered at an average of 58 d of age; LATE = 36 mg zeranol administered at an average of 121 d of age (initially 9 steers/pen and 5 pens/treatment).

³Probability of difference among least squares means.

(Horwitz, 2000; method 960.39) with the exception that a Soxhlet extractor (model 80068-154; Chemglass Life Sciences LLC, Vineland, NJ) was used with petroleum ether instead of a Goldfish apparatus. Ether extraction occurred for 60 h followed by evaporation of samples at room temperature prior to tin placement in an oven at 101°C for 4 h (Bruns et al., 2004). Dried, extracted samples were placed in desiccators for 1 h and then reweighed. Crude fat was calculated as the difference between pre- and postextraction sample weight and expressed as a percent of the pre-extraction sample weight.

Economic Analysis

Total carcass value and carcass value per 45.4 kg (hundredweight) were based on plant assigned premiums and discounts using the Angus America Grid.

Statistical Analysis

Influence of nursing implant treatments was evaluated using PROC MIXED of SAS (SAS Inst. Inc., Cary, NC) in a randomized complete block design with pens during the finishing phase as experimental units. Live animal data including BW, ADG, and ultrasound measurements (uREA, uRFT, and uIMF) were analyzed by implant treatment, period of time (LATE implant administration, weaning, initial feed yard implant, final feed yard implant, and slaughter), and the treatment $\times$ period interaction as fixed effects. Block was specified as a random effect. Period was considered a repeated measure. Initial steer BW at the administration of the

EARLY implant on June 9 was used as a covariate for BW, ADG, DMI, and G:F to account for differences in BW of the cattle before implant treatments were applied. Gain in uREA, uRFT, and uIMF between each period (calculated as difference between periods) was also analyzed using the same model. Initial ultrasound scan data collected June 9 was used as a covariate. Carcass data including HCW, REA, FT, USDA yield grade, marbling score, overall maturity, color, percent lipid and moisture, and carcass value (expressed as value per 45.4 kg [hundredweight] and value per total carcass) were analyzed by nursing implant treatment. Steak WBSF and percent cook loss were evaluated with 3- and 14-d aging periods as repeated measures. Peak internal cooking temperature was used as a covariate for both WBSF and percent cook loss. For all analyses that included a repeated measure, the variance-covariance structure for each response variable was selected based on the Schwarz's Bayesian information criteria fit statistic. Influence of nursing implant treatments on the proportion of carcasses assigned to each USDA quality and yield grade were analyzed using a binary distribution in PROC GLIMMIX of SAS. Nursing implant treatment was tested as a fixed effect with block specified as a random effect. Denominator degrees of freedom were approximated using the Kenward-Roger option in the model statement for all analyses. Least squares means and SEM were computed for all variables and separated using least significant differences (PDIF) when tests of fixed effects were significant. Results were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Animal Performance and Ultrasound Measurements

There were no interactions ($P > 0.05$) between treatment and period for most response variables (except incremental changes in uREA and uRFT discussed below). Therefore, main effects for cattle performance by treatment and period are reported. Body weight, ADG, and G:F of steers did not differ among treatments for the duration of the project ($P > 0.05$; Table 2). Furthermore, lack of a treatment $\times$ period interaction ($P = 0.423$) for BW (Table 3) indicated that preweaning implants did not influence growth, even during the periods that preweaning implants were active. Although this lack of response was unexpected, other researchers have reported variable responses to preweaning implants (Mader et al., 1985; Simms et al., 1988). Selk (1997) reported that suckling implants provide a 5 to 6% increase in ADG. In a review of implant strategies, Duckett and Andrae (2001) acknowledged inconsistent responses to suckling implants across various studies and indicated that the response is

Table 3. Least squares means for effect of nursing implant timing on BW (kg) at each time steers were weighed

Weigh date ¹	Treatment ²		
	CON	EARLY	LATE
August 11, 2014	186.73 ³	192.19	185.31
October 27, 2014	266.77	272.84	272.74
November 18, 2014	281.45	284.28	286.40
February 12, 2015	437.03	435.60	441.99
May 6 or 27, 2015 ⁴	586.75	593.83	594.96

¹Initial calf BW on June 9 used as a covariate.

²Treatments: CON = control (no calf implant); EARLY = 36 mg zeranol administered at an average of 58 d of age; LATE = 36 mg zeranol administered at an average of 121 d of age (initially 9 steers/pen and 5 pens/treatment).

³SEM 5.179. Response of BW displayed a time main effect ($P < 0.0001$; data not shown) but did not display a treatment main effect ($P = 0.717$) or a treatment $\times$ time interaction ($P = 0.423$).

⁴Steers were harvested at a targeted 1 cm of 12th-rib fat thickness; steers finished earlier by block were slaughtered May 6, 2015, and the remaining steers, by block, were slaughtered May 27, 2015.

greater when suckling calves are on a higher plane of nutrition. In a study conducted by Woods et al. (1990), zeranol implants resulted in an increased ADG of nursing steer and heifer calves compared with nonimplanted controls; however, weaning weight only tended to increase ($P < 0.08$). Mader et al. (1985) reported no difference in weaning weight when zeranol implants were administered to suckling calves compared with nonimplanted controls and that preweaning implants may depress the subsequent response of postweaning implants. Conversely, Simms et al. (1988) reported that implanting with zeranol did not improve ADG of suckling steer calves and that preweaning implants did not differentially influence performance in the finishing phase. Simms et al. (1988) and Mader et al. (1985) evaluated the use of zeranol implants throughout all phases of production. In the present study, zeranol was administered to nursing calves but more aggressive implants were used in the finishing phase. More recently, Pritchard et al. (2015) investigated the influence of time of administration of Synovex C (10 mg of estradiol benzoate and 100 mg of progesterone; Zoetis, Florham Park, NJ) implants to suckling calves and reported that although both May and August implant treatments increased weaning weight of steer calves compared with nonimplanted controls, there was an interaction with dam age. Steer calves implanted in May raised by mature (≥ 4 yr) cows were heavier than those raised by immature (< 4 yr) cows. Additionally, the presence of a suckling implant did not influence carcass traits (Pritchard et al., 2015). Conversely, Platter et al. (2003) reported that Synovex C implants provided at branding had no influence on weaning weight.

Steers that were implanted in the EARLY treatment had a greater ($P < 0.05$) cumulative DMI than CON but were not different from steers implanted in the LATE

Figure 2. Rib eye area gain (cm²) of steers administered a control (CON; no preweaning implant), implanted at 58 d of age (EARLY; 36 mg zeranol; Ralgro [Merck Animal Health, Madison, NJ] at branding; administered at an average of 58 d of age), or implanted at 121 d of age (LATE; 36 mg zeranol in mid August; administered at an average 121 d of age). Gain was calculated as final measurement of each period minus initial measurement of the period. ^{a,b}Means within a time period without a common letter differ ($P < 0.05$).

treatment (Table 2). It is understood that without adequate nutrition, the response to implantation will be limited (Kuhl, 1997). However, the 0.4-kg difference in DMI between steers implanted in the EARLY treatment and CON is difficult to explain because ADG and G:F were not different ($P > 0.05$). As expected, there was a period effect for BW and ADG ($P < 0.001$) as steers grew over the duration of the study. The ADG were appropriate for nursing (1.08 ± 0.01 kg), backgrounding (0.60 ± 0.03 kg), receiving (1.79 ± 0.03 kg), and finishing (1.68 ± 0.03 kg) periods. However, no cumulative ADG difference was detected (Table 2). These results are in agreement with Platter et al. (2003), Mader et al. (1985), and Mader (1994), who reported that implants provided during the suckling phase did not influence the lifetime weight gains when 2 or 3 additional implants are administered during the subsequent growing and finishing phases.

To document effects of implant treatments on body composition throughout the study, steers were periodically ultrasounded. When uREA and uRFT were averaged across all periods (i.e., treatment main effect), no differences ($P > 0.05$) were detected as a result of implant treatment (Table 2). Control steers had a greater ($P < 0.05$) percent uIMF than EARLY implanted steers, whereas LATE implanted steers were intermediate and not different from the other treatments (Table 2). As expected, the main effect for period indicated that uREA, uRFT, and uIMF all increased ($P < 0.001$) as the steers grew. On August 11, steers averaged $3.27 \pm 0.094\%$ uIMF, and values increased over time (3.30 ± 0.094 , 4.05 ± 0.094 , and $4.52 \pm 0.086\%$ for November 18, February 12, and the morning of harvest, respectively).

Timing of nursing implant administration interacted with period for gain in uREA and uRFT ($P < 0.05$; Fig. 2 and 3). The incremental gain in uREA was enhanced ($P <$

Figure 3. Rib fat thickness gain (cm) of steers administered a control (CON; no preweaning implant), implanted at 58 d of age (EARLY; 36 mg zeranol; Ralgro [Merck Animal Health, Madison, NJ] at branding; administered at an average of 58 d of age), or implanted at 121 d of age (LATE; 36 mg zeranol in mid August; administered at an average 121 d of age). Gain was calculated as final measurement of each period minus initial measurement of the period. ^{a,b}Means within a time period without a common letter differ ($P < 0.05$).

0.05) during the period that the EARLY nursing implant was active (June to August) but was not enhanced by the LATE implant when it was active (August to November; Fig. 2). Additionally, incremental gain in uREA by the EARLY implanted group was depressed ($P < 0.05$) after the implant was no longer active (August to November). Gain in uRFT was depressed ($P < 0.05$) in EARLY implanted steers compared with the CON steers when the implant was active (June to August; Fig. 3). In a similar fashion, gain in uRFT was depressed ($P < 0.05$) in LATE implanted steers relative to EARLY implanted steers when the LATE implant was active (August to November; Fig. 3). Responses to the early implant in uREA and uRFT gain appear to be offset during late summer, resulting in no differences in uREA and uRFT at weaning. Postweaning responses were not influenced by suckling implants because no differences in uREA or uRFT gain were detected from November to harvest.

Carcass Attributes

Hot carcass weight, REA, FT, USDA yield grade, marbling score, overall maturity, and objective color (L^* , a^* , and b^*) did not differ among treatments ($P > 0.05$; Table 4), suggesting that nursing implants, regardless of timing, did not influence carcass characteristics. These results are consistent with Platter et al. (2003), who reported that implants provided at branding had no effect on HCW, loin muscle area, fat thickness, or USDA yield grade. Mader et al. (1985) reported that the initial weight of steers provided a zeranol implant at branding (1 to 2 mo of age) was greater at weaning and at the initiation of the growing phase; however, the benefit of a suckling implant was diminished by harvest, as carcass weights were similar. Additionally, consistent with the present study, no

differences were reported for REA, fat thickness, KPH, or USDA yield or quality grade (Mader et al., 1985).

The proportion of steers in each USDA yield and quality grade did not differ among treatments (Table 4). Consequently, there were no differences among treatments for price per 45.4 kg (hundredweight) or total carcass value ($P > 0.05$; Table 4). Carcass performance results illustrate that steers successively implanted (3 implants) can grade USDA Low Choice as can steers implanted only in the feed yard phase (2 implants). This result was consistent with that of Smith et al. (2007), who determined that anabolic implants did not directly affect intramuscular lipid, especially when cattle have the genetic propensity to deposit marbling. Research conducted by Platter et al. (2003) provided evidence that implanting steers at branding, weaning, or backgrounding prior to finishing did not affect marbling score or the percent of cattle grading choice or prime. However, Platter et al. (2003) reported that administering implants twice produced carcasses with greater marbling scores than steers receiving 4 or 5 lifetime implants.

Warner–Bratzler Shear Force Evaluation

There was no interaction ($P = 0.88$) between treatment and aging period, although tenderness of all steaks improved ($P \leq 0.05$) with aging (3.56 ± 0.131 kg at 3 d versus 2.89 ± 0.092 kg at 14 d). Overall, WBSF, percent cook loss, percent moisture, and percent crude fat were not influenced by treatment ($P > 0.05$; Table 4). Therefore, it is probable that the implant strategies used in this study were not aggressive enough to influence mechanisms regulating tenderness. Research evaluating the influence of successive implants on objective tenderness is mixed. Tatum (1993) and Roeber et al. (2000) suggested that successive implantation or repetitive use of implants may be detrimental to tenderness. Duckett and Pratt (2014) cautioned that using more than 2 implants in the finishing period can increase WBSF. However, Platter et al. (2003) discovered no difference in WBSF when steers were implanted at branding or weaning followed by feed yard implants. Furthermore, Schoonmaker et al. (2001) suggested that successive lifetime implant strategies for steers do not affect shear force values.

Implications

Timing of nursing implant did not influence overall live performance, carcass characteristics, or meat quality of steers fed in this study. Additionally, preweaning implantation did not influence performance during the suckling phase, suggesting no differential advantage for the cow–calf producer. There were no

Table 4. Least squares means for effect of nursing implant timing on carcass characteristics, meat quality and carcass value

Variable	Treatment ¹			SEM	P-value ²
	CON	EARLY	LATE		
HCW, kg	357	362	361	8.914	0.773
Rib eye area, cm ²	98.16	98.58	97.12	1.540	0.792
12th-rib fat thickness, cm	2.037	2.027	2.057	0.097	0.937
USDA yield grade	3.01	3.02	3.11	0.118	0.442
Marbling score ³	466	473	468	12.207	0.912
Overall maturity ⁴	149.11	144.42	143.85	2.113	0.197
L* ⁵	43.41	43.9	43.01	0.224	0.472
a* ⁶	25.27	25.41	25.23	0.349	0.831
b* ⁷	11.48	11.55	11.42	0.284	0.817
WBSF, ⁸ kg	3.19	3.14	3.34	4.440	0.190
Cook loss, ⁹ %	18.93	18.97	18.91	0.875	0.995
Lipid, ¹⁰ %	5.00	5.29	4.99	0.003	0.327
Moisture, ¹⁰ %	71.53	71.39	71.61	0.236	0.363
USDA quality grade ¹¹					
Select (Slight 0–99), %	20.00	11.11	16.67	0.068	0.754
Low Choice (Small 0–99), %	48.84	56.82	56.82	0.074	0.702
Certified Angus Beef (Modest 0 to Moderate 99), %	34.88	38.64	36.36	0.073	0.936
USDA yield grade ¹¹					
Yield grade 1, %	11.76	15.38	11.11	0.078	0.926
Yield grade 2, %	41.86	38.64	54.55	0.075	0.389
Yield grade 3, %	51.16	50	36.36	0.076	0.355
Total carcass value, ¹² US\$	2,005	2,053	2,046	85.77	0.146
Carcass value per 45.4 kg (hundredweight), ¹² \$	254	256	255	2.03	0.253

¹Treatments: CON = control (no calf implant); EARLY = 36 mg zeranol administered at an average of 58 d of age; LATE = 36 mg zeranol administered at an average of 121 d of age (initially 9 steers/pen and 5 pens/treatment).

²Probability of difference among least squares means.

³Marbling score: 2⁰⁰ = Traces⁰; 3⁰⁰ = Slight⁰; 4⁰⁰ = Small⁰; 5⁰⁰ = Modest⁰.

⁴Combined skeletal maturity and lean maturity: 100 = A0; 200 = B0; 300 = C0.

⁵L*: 0 = black and 100 = white; recorded 3 d postmortem.

⁶a*: negative values = green and positive values = red; recorded 3 d postmortem.

⁷b*: negative values = blue and positive values = yellow; recorded 3 d postmortem.

⁸Kilograms of force measured by Warner–Bratzler shear force (WBSF); peak internal cooking temperature used as a covariate.

⁹Percent weight loss after cooking; peak internal cooking temperature used as a covariate.

¹⁰Percent of raw steak composition.

¹¹Assigned by USDA grader; no steers received a quality grade lower than USDA Select or greater than Certified Angus Beef or a yield grade greater than 3.

¹²Determined based on plant premiums and discounts on the day of slaughter.

repercussions of nursing implants on USDA quality grade, but nursing implants did not provide any advantages in terms of animal performance or carcass quality regardless of when they were administered. Therefore, it may not be efficacious for producers to administer nursing implants to calves under production conditions similar to those described in this study.

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