Effects of coated and noncoated steroidal implants on growth performance, carcass characteristics, and serum estradiol-17β concentrations of finishing Holstein steers

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ABSTRACT: The objectives of the study were to determine the effect of coated or noncoated hormone implants on growth performance, carcass characteristics, and serum estradiol-17β (E_2) concentrations of Holstein steers fed a grain-based diet for 112 d. Seventy-nine Holstein steers [average initial body weight (BW) = 452 ± 5.5 kg] were stratified by BW and allotted to one of two treatments: 1) Holstein steers implanted with a coated implant containing 200 mg of trenbolone acetate (TBA) and 40 mg E_2 (Revalor-XS (Merck Animal Health; Summit, NJ)] on day 0 (XS) or 2) Holstein steers implanted two times (days 0 and 56) with a noncoated implant containing 80 mg of TBA and 16 mg of E_2 [(2IS) Revalor-IS (Merck Animal Health)]. Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). There was no effect ($P \geq 0.71$) of implant strategy on initial, middle, and final BW. No effect ($P \geq 0.12$) of implant strategy was observed on average daily gain, dry matter intake, or gain-to-feed ratio. There were no effects ($P \geq 0.11$) of implant strategy on carcass characteristics. There was an implant × day interaction ($P < 0.01$) for the circulation of serum E_2 concentrations. Serum E_2 concentration increased similarly 14 d after Holstein steers were implanted, regardless of implant strategy. At 28 d, after steers were implanted, steers in the XS group had less serum E_2 concentration than Holstein steers in the 2IS group. However, at 56 d after the first implantation, both groups, once again, had similar serum E_2 concentrations and E_2 concentrations were less on day 56 than day 28 for both strategies. Holstein steers implanted with 2IS had greater serum E_2 concentration on day 70 and E_2 concentrations remained greater than serum E_2 of Holstein steers implanted XS for the duration of the trial (day 112). In summary, there was no effect of coated or two doses of noncoated implant on growth performance or carcass characteristics of Holstein steers.

Key words: carcass characteristics, estradiol-17β, Holstein, steers, trenbolone acetate

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INTRODUCTION

Approximately 90% of all feedlot cattle in the United States receive steroidal hormone implants during the finishing phase of production (National Animal Health Monitoring System, USDA 2011). Steroidal implants have been used in beef cattle production to improve growth performance and feed efficiency for over 50 yr (Preston, 1999). Although previous research has suggested a payout period of 90–120 d on noncoated implants (Mader, 1998). Carvalho et al. (2020) observed

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a significant decrease in serum estradiol-17β (E_2) concentration and average daily gain (ADG) of Holstein steers 56 d after steers were implanted with an 80-mg trenbolone acetate (TBA) and 16-mg E_2 noncoated implant and demonstrated that Holstein steers had shorter implant payout period than what has been previously reported in traditional beef breeds. In the last 13 yr, coated implant technologies have been made available to extend the payout period of hormone implants to up to 200 d postimplantation (Smith and Johnson, 2020).

Information about the biological responses of coated implants on traditional beef breeds are well documented (Parr et al., 2011, 2014; Smith et al., 2018). The recent increase in the number of Holstein cattle fed for slaughter in the United States has increased the attention surrounding the use of hormone implant technologies in finishing Holstein beef steers (Carvalho et al., 2020). In addition, there is a dearth of information regarding growth performance, carcass characteristics, and hormonal payout period of Holstein steers implanted with different strategies during the finishing phase in the feedlot.

Therefore, we hypothesized that implanting Holstein steers with two doses of an 80-mg TBA and 16-mg E_2 noncoated implant in a 56-d interval would prevent the decrease ADG and serum E2 concentration prior to reimplantation; and we also hypothesize that the use of a coated implant with a 200 mg of TBA and 40 mg E_2 would result in similar growth performance, by maintaining a consistent serum E2 concentration, without the need to reimplant. The objectives of the study were to determine the effect of noncoated or coated hormone implants on growth performance, carcass characteristics, and serum E_2 concentrations of Holstein steers fed a grain-based diet.

MATERIALS AND METHODS

All procedures involving the use of animals were approved by The Pennsylvania State University Institutional Animal Care and Use Committee (#201800037) and followed the guidelines recommended in the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010).

Animal and Diet Management

Seventy-nine Holstein steers [average initial body weight (BW) = 452 ± 5.5 kg, 12–15 mo of age] were used for this experiment at the Pennsylvania Department of Agriculture Livestock Evaluation Center, Pennsylvania Furnace, PA. Steers were housed in a confinement barn. The facility was a gable roof barn with interior pen, constructed of metal gates and cables, on concrete floor (30.5 × 7.5 m per pen) that was open on the back side to an exterior gravel lot (30.5 × 61 m per pen). A feed alley on the interior of the building was equipped with GrowSafe automated feeding systems (Model 4000E, GrowSafe Systems Ltd., Airdrie, AB Canada) and there were six GrowSafe feed bunks per pen (12 GrowSafe feed bunks total).

Individual animal feed intakes were monitored daily using the GrowSafe Feeding System by trained personnel. Fresh feed was supplied to each bunk daily from 0900 to 1000 h. According to GrowSafe Feeding System standards, intake data were considered acceptable if both 85% of the feed supplied and 90% of the feed that disappeared from the bunk within the pen could be attributed to steers assigned to those bunks via electronic identification. Intake data were discarded if it did not meet these criteria on any given day. At the end of the experiment, 96% of the total fed days were included in the data to be reported for dry matter intake (DMI) values.

All steers were adapted to a corn-based diet for 28 d (days −28 to −1) before the feeding experiment began. Diet was fed once a day from 0900 to 1000 h, and bunks were managed on a "slick bunk" management system. The first adaptation diet contained 30% dry corn, 50% corn silage, 10% grass hay, 8% soybean meal, and 2% supplement [dry matter (DM) basis]. Every 7 d, corn replaced 12.5% (DM basis) of the corn silage in the diet until the final diet was fed. The final diet was composed of 81.5% dry corn, 10% grass hay, 6.5% soybean meal, and 2% mineral and vitamin supplement (DM basis; Table 1).

Once steers were adapted to the finishing diet, they were weighed on two consecutive days (days 0 and 1) to determine initial full BW. Steers were stratified by BW on day 0 and allotted to one of two pens (38 and 40 steers per pen) on day 1 such that each pen had a similar initial average BW. Steers were assigned to one of two treatments: (XS) Holstein steers implanted with a coated implant with 200 mg TBA and 40 mg E_2 [Revalor-XS (Merck Animal Health; Summit, NJ), 80 mg TBA and 16 mg E_2 (noncoated), and 120 mg TBA and 24 mg E_2 (coated, polymer coating is proposed to degrade entirely by day 70 following implant administration)] on day 0 or (2IS) Holstein steers implanted two times (days 0 and 56) with a noncoated

Table 1. Composition of diet fed to Holstein steers

Ingredients, % DM basis	
Corn	81.5
Hay	10.0
Soybean meal	6.5
Mineral and vitamin supplement[a]	2.0
Analyzed nutrient composition, % DM basis	
Crude protein	11.38
Neutral detergent fiber	16.94
Starch	61.86
NE_m[b], Mcal/kg	1.96
NE_g[c], Mcal/kg	1.31

[a]Mineral and vitamin supplement = 1,550 g/1,000 kg Rumensin 90 (198 g of monensin/kg of DM; Elanco Animal Health, Greenfield, IN), Ca 25%, NaCl 15%, Mg 1%, K 3.5%, Zn 1,000 mg/kg, Cu 180 mg/kg, Se 16 mg/kg, and Vit A 59,020 IU/kg (Agri-Basics, Inc., Elizabethtown, PA).

[b]Net energy for maintenance based on NRC (2000).

[c]Net energy for gain = 0.877 NE_m − 0.41.

implant with 80 mg TBA and 16 mg E_2 [Revalor-IS (Merck Animal Health)]. Thus, each pen had a similar number of steers per treatment.

Individual steer BW was recorded (0.454 kg accuracy on W-W Paul Scales, model #300-S; Duncan, OK) on days 14, 28, 56, 57, 70, 84, 111, and 112, relative to trial initiation. Middle and final BW were collected on two consecutive days (days 56 and 57 and days 111 and 112, respectively). Steers were not denied feed prior to weighing. Overall ADG was calculated as the average of the two final BW measurements minus the average of the two initial BW measurements divided by the total number of days on feed (112 d). This calculated ADG for each steer was divided by the average daily DMI of each steer to calculate the gain-to-feed ratio (G:F).

Serum E_2 Concentration

Whole blood was collected from the jugular vein into 15-mL red top vacutainer tubes (Becton, Dickinson and Co., Franklin Lakes, NJ) on days 0, 14, 28, 56, 70, 84, and 112. Blood was allowed to clot for 24 h at 4 °C and subsequently centrifuged at 1,250 × *g* at 4 °C for 15 min. Serum was harvested and stored at −20 °C until analysis.

Serum E_2 concentration was determined on all serum samples via radioimmunoassay (RIA) procedures using methods described by Perry and Perry (2008). Cross-reactivity of the antibody used were 100% for E_2, 6.5% for estriol, 5.2% for estradiol-17α, 0.6% for estrone, and <0.01% for aldosterone, androstenedione, cholesterol, progesterone, and testosterone. The intra-assay and interassay coefficients of variation for the E_2 assay were 6.39% and 6.94%, respectively, and assay sensitivity was 0.4 pg/mL.

Carcass Data Collection

On day 112, steers were transported for 320 km to an abattoir (JBS Inc., Souderton, PA) and were humanely slaughtered under USDA inspection. On the same day, hot carcass weight (HCW) was collected. Carcasses were chilled for 48 h at 4 °C. Approximately 48 h postharvest, the carcasses were ribbed between the 12th and 13th ribs and carcass data, including fat thickness at the 12th rib, marbling score, and longissimus muscle area (LMA), were collected by Penn State-trained personnel at the plant. The USDA Quality Grade (QG) was assigned by the plant and the Yield Grade (YG) was calculated using the USDA equation (USDA, 1997). On the day that carcass samples were collected, the kidney, pelvic, heart fat (KPH) had already been removed from the carcass; therefore, the percentage of KPH was not reported in the current experiment and 2.5% KPH was used in the calculated YG equation.

Statistical Analysis

The experimental design for this study was a randomized complete block design. To evaluate the effects of implants on growth performance and carcass characteristics, data were analyzed using the MIXED procedure of SAS (v9.4 SAS Inst., Inc., Cary, NC). The model was:

$$Y_{\text{ijk}} = \mu + p_i + I_j + e_{\text{ijk}}$$

where Y_{ijk} = response variable; μ = mean; *pi* = random effect of pen; *Tj* = the fixed effect of treatment; and e_{ijk} = the experimental error.

Categorical carcass characteristics (QG) were analyzed using the GLIMMIX procedure of SAS (v9.4 SAS Inst., Inc.) using a binomial distribution and a Satterthwaite adjustment. To evaluate the effects of hormone implant on serum E2 concentration over time (days on feed), data were analyzed using the MIXED procedure of SAS (v9.4 SAS Inst., Inc.) with repeated measures. The statistical model for the effect of implant and day was:

$$Y_{\text{ijkl}} = \mu + p_i + D_j + T_k + (\text{DT})_{\text{jk}} + e_{\text{ijkl}}$$

where Y_{ijkl} = response variable; μ = mean; *pi* = random effect of pen; *Dj* = the fixed effect of day of collection; *Tk* = the fixed effect of implant treatment; $(DT)_{jk}$ = the fixed effect of the interaction of day of collection and implant treatment; e_{ijkl} = the experimental error. The covariance structure compound symmetry was selected based on the lowest Bayesian information criterion. For all parameters, steer was the experimental unit and significance was declared at $P \leq 0.05$.

RESULTS AND DISCUSSION

Although previous research has suggested a payout period of 90–120 d on noncoated implants (Mader, 1998), Carvalho et al. (2020) observed a significant decrease in serum E_2 concentration and ADG of Holstein 56 d after steers were implanted with an 80-mg TBA and 16-mg E_2 noncoated implant. Therefore, these authors suggested that Holstein steers implanted with a mild hormone implant should be reimplanted in a shorter window to obtain maximum performance in the feedlot (Carvalho et al., 2020). Thus, the primary objective of the current experiment was to compare a coated hormone implant (XS) administered 112 d prior to slaughter or two doses of a noncoated implant administered at equally spaced intervals (days 0 and 56) in steers fed for 112 d prior to slaughter.

There was no effect ($P \geq 0.83$) of hormone implant on the middle and final BWs (Table 2). The lack of differences in BW changes is a result of similar ($P \geq 0.55$) ADG throughout the experiment between the two implant strategies. Similar ADG between coated and two doses of noncoated implants were also reported by Parr et al. (2011) when crossbred beef steers were kept on feed for 131 d. However, greater ADG for crossbred beef steers implanted with XS implant were observed if cattle were kept on feed for 174 or 197 d, suggesting that two doses of noncoated implants have a shorter payout period than a single dose of coated implant (Parr et al., 2011). Carvalho et al. (2020) reported that Holstein steers implanted with an 80-mg TBA and 16-mg E_2 noncoated implant had a decrease in ADG 56 d after the first implantation. However, data from the current experiment suggests that reimplanting Holstein steers with similar noncoated implant on day 56 prevented the decrease in ADG from day 56 to day 84 (Fig. 1).

Table 2. Effects of coated and noncoated steroidal implants on growth performance of finishing Holstein steers.

	XS[a]	2IS	SEM	*P*-value
Steers, *n*	38	40		
Live weight[b], kg				
Initial	453	450	5.5	0.71
Middle	565	564	6.1	0.91
Final	653	651	6.5	0.83
ADG, kg/day	1.78	1.79	0.035	0.86
DMI, kg/day	12.29	11.88	0.253	0.24
G:F[c]	0.146	0.152	0.0029	0.28

[a]XS = Holstein steers implanted with a coated implanted with 200 mg of TBA and 40 mg E_2 [Revalor-XS (Merck Animal Health; Summit, NJ); 80 mg TBA and 16 mg E_2 (noncoated) and 120 mg TBA and 24 mg E_2 (coated, polymer coating is proposed to degrade entirely by day 70 following implant administration)] on day 0; 2IS = Holstein steers implanted two times (days 0 and 56) with 80 mg of TBA and 16 mg of E_2 [Revalor-IS (Merck Animal Health)].

[b]Initial, middle, and final full BW were calculated as the average BW of days 0 and 1, days 56 and 57, and days 111 and 112, respectively.

[c]G:F was calculated as the steer ADG divided by steer average DMI within each period.

There was no effect of hormone implant on DMI ($P \geq 0.24$) or G:F (Table 2). Parr et al. (2011) also reported similar feed efficiency when crossbred beef steers received either single-coated implant or two doses of noncoated implant (IS/S), regardless of the number of days that animals stayed on feed (131, 174, 197, or 243 d) or the interval (46, 70, 71, and 96 d) between two implantations. Thus, when implantation is spaced in short intervals, results in Holsteins steers are comparable.

There were no effects ($P \geq 0.11$) of implant strategy on the carcass characteristics measured in the current experiment (Table 3). Despite the implant used, Holstein steers had similar HCW, dressing percentage, LMA, marbling score, fat thickness, YG, and QG distributions. Similar HCW between cattle implanted with coated and two doses of noncoated implants have been reported by Parr et al. (2011); however, these authors observed that two doses of noncoated implant decreased the percentage of carcass being graded USDA choice QG when cattle were on feed for only 131 d postimplantation. While there was no impact of implant strategy on USDA QG in the current trial with Holsteins steers, steers implanted with coated implant had almost 15 percentage units decrease in the number of carcass that was classified as USDA choice or greater. The coated implant used in the current experiment was designed to have a second pool of hormone release around 70–80 d postimplantation; this is 2 wk after the second implantation on the 2IS group. Therefore, this later pool of hormone release might also have contributed to a delay in fat deposition and subsequent numerical decrease in QG of Holstein steers in the XS group. While this problem could perhaps be avoided if animals were implanted earlier or stayed more days on feed, Revalor-XS is one of the only steroid hormones for steers on the market that is labeled "may

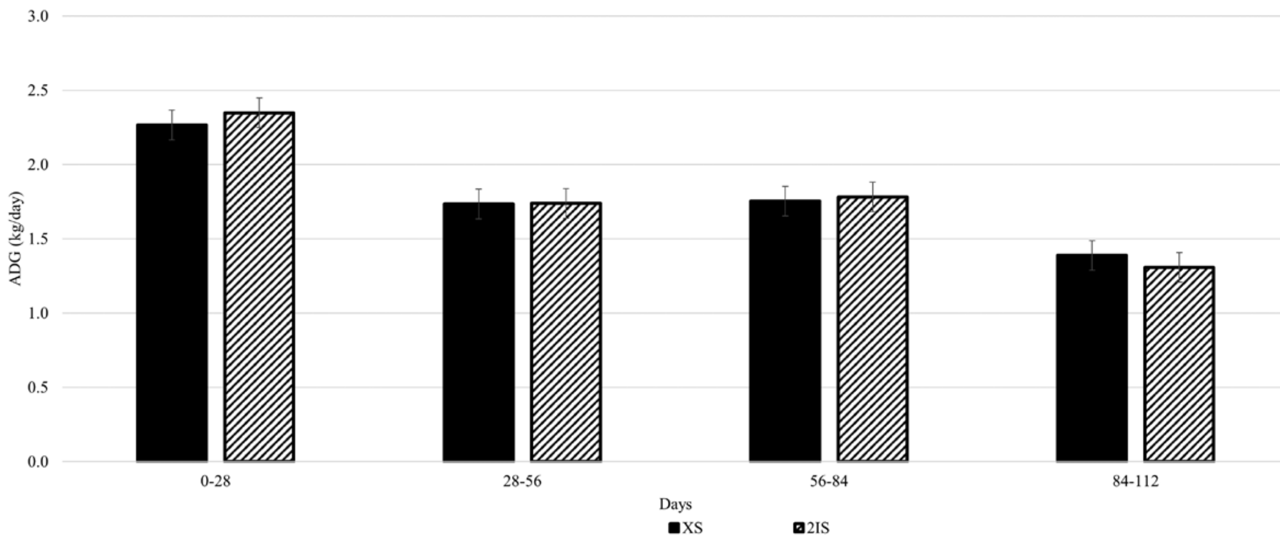

Figure 1. Effects of coated and noncoated steroidal implants on ADG of Holstein steers (kg/d). Solid bar = Holstein steers implanted with a coated implant with 200 mg of TBA and 40 mg E_2 [Revalor-XS (Merck Animal Health; Summit, NJ); 80 mg TBA and 16 mg E_2 (noncoated) and 120 mg TBA and 24 mg E_2 (coated, polymer coating is proposed to degrade entirely by day 70 following implant administration)] on day 0. Dash bar = Holstein steers implanted two times (days 0 and 56) with 80 mg of TBA and 16 mg of E_2 [Revalor-IS (Merck Animal Health)]. The error bars reflect the SEM (0.106).

Table 3. Effects of coated and noncoated steroidal implants on Holstein steers carcass characteristics.

	XS[a]	2IS	SEM	*P*-value
Steers, *n*	38	40		
HCW, kg	370	371	4.4	0.84
Dressing percentage, %	59.0	59.3	0.30	0.38
LMA, cm[b]	72.8	73.7	2.62	0.57
Marbling score	476	485	20.8	0.73
Fat thickness, cm	0.54	0.58	0.069	0.58
YG[c]	2.42	2.70	0.211	0.15
USDA QG Choice and above[d], %	69.42	85.32	10.680	0.11

[a]XS = Holstein steers implanted with a coated implanted with 200 mg of TBA and 40 mg E_2 [Revalor-XS (Merck Animal Health; Summit, NJ); 80 mg TBA and 16 mg E_2 (noncoated) and 120 mg TBA and 24 mg E_2 (coated, polymer coating is proposed to degrade entirely by day 70 following implant administration)] on day 0; 2IS = Holstein steers implanted two times (days 0 and 56) with 80 mg of TBA and 16 mg of E_2 [Revalor-IS (Merck Animal Health)].

[b]For marbling score, Slight = 200–299; Small = 300–399; Modest = 400–499; Moderate = 500–599.

[c]Carcass YG was calculated according to the USDA regression equation (USDA, 1997).

[d]Percentage of carcasses grade USDA choice or above.

reduce quality grades" (FOIS, 2007). However, even in light of the shorter duration on the implant and the moderate differences in percentage between the two treatment groups, nearly 70% of the steer implants with XS still graded USDA Choice or above.

In addition, because the trial lasted only 112 d, the serum hormone concentrations were still elevated at the end of the experiment. There was an interaction between hormone implant and day ($P < 0.01$; Fig. 2). Serum E_2 concentrations were similar at the beginning (day 0) of the experiment and had a similar increase 14 d after Holstein steers were implanted. On day 28, steers implanted with XS had decreased circulating concentration of serum E_2 compared to 2IS. However, by 56 d after the first implantation, both groups decreased circulating concentrations of serum E_2 and did not differ from one another. Holstein steers in the 2IS group received their second implant on day 56 and had greater serum E_2 concentration than Holstein steers in the XS group on day 70 of the experiment. Serum E_2 in Holstein steers remained greater in the Holstein steers implanted with two doses of noncoated implant (2IS) than serum E_2 of Holstein steers implanted with coated (XS) implant.

Carvalho et al. (2020) reported that, as serum E_2 concentration increases, Holstein steers had increased ADG but that increase in E_2 and subsequent ADG may be less than expected when compared to implanted beef steers. Even though serum E_2 concentrations remained elevated during the last 56 d of the feedlot, and in fact were greater in the 2IS group, those differences between the implant strategies did not have a positive effect on Holstein steers ADG (Fig 1). According to Mader (1998), a slow decline in serum E_2 concentration after a peak generally can maintain greater ADG as long as hormone concentration remains elevated. Although several experiments have estimated serum E_2 concentration between implanted and nonimplanted cattle, the specific concentration that serum E_2 needs to remain above to maintain

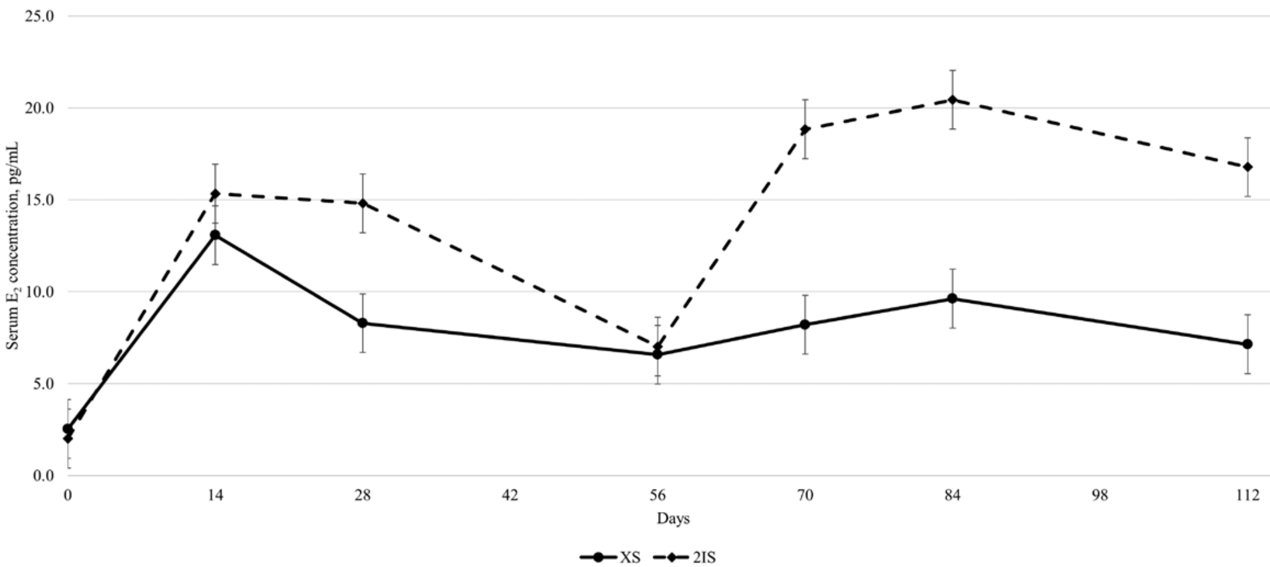

Figure 2. Effects of coated and noncoated steroidal implants on serum E_2 concentration (pg/mL) of Holstein steers over time. Solid bar = Holstein steers implanted with a coated implant with 200 mg of TBA and 40 mg E_2 [Revalor-XS (Merck Animal Health; Summit, NJ); 80 mg TBA and 16 mg E_2 (noncoated) and 120 mg TBA and 24 mg E_2 (coated, polymer coating is proposed to degrade entirely by day 70 following implant administration)] on day 0. Dash bar = Holstein steers implanted two times (days 0 and 56) with 80 mg of TBA and 16 mg of E_2 [Revalor-IS (Merck Animal Health)]. There was an implant × day of the study interaction ($P < 0.01$). The error bars reflect the SEM associated with the interaction of implant × day of the study (SEM = 1.606). The * above each time point reflects a difference ($P < 0.01$) between treatments.

a greater ADG is unknown. Using data from recent publications that measured serum E_2 concentration from coated and noncoated implanted cattle versus nonimplanted cattle (Parr et al., 2011; Smith et al., 2018; Carvalho et al., 2020), it appears that, as long as serum E_2 concentration levels is above 5 pg/mL, it has a positive response in cattle growth. Although a nonimplanted group was not used on the current experiment, both groups maintained their serum E_2 concentration above 5 pg/mL and had similar ADG even though serum E_2 concentrations were different between groups.

CONCLUSIONS

The objectives of our study were to determine the effect of noncoated or coated hormone implants on growth performance, carcass characteristics, and serum E_2 concentrations of Holstein steers fed a grain-based diet. Although serum E_2 concentrations were different between Holstein steers implanted with two doses of the same noncoated implant (80 mg of TBA and 16 mg of E_2) and those implanted with a coated implant (200 mg of TBA and 40 mg of E_2), growth performance and carcass characteristics did not differ between implant strategies. These data suggest that managers of Holstein cattle can use only one implant, as long as it has an extended release, during the last 112 d on feed to finish Holstein steers in the feedlot.

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Conflict of interest statement. The authors have no conflicts of interest to declare.

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