Delay implant strategy in calf-fed Holstein steers: growth performance and carcass characteristics

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ABSTRACT

The influence of live weight (LW) at first implanting on growth performance and carcass characteristics was evaluated in calf-fed Holstein fed a steam-flaked corn-based diet. Treatments were: (1) control (not implanted); (2) first implanted at 267 kg LW; (3) first implanted at 291 kg LW, and (4) first implanted at 321 kg LW. All implanted cattle were re-implanted on d-112 of trial. Both the initial and final implants contained 120 mg of trenbolone acetate and 24 mg of oestradiol. Compared with non-implanted controls, implanting increased (P < .01) overall dry matter intake (DMI, 5.9%), average daily gain (ADG, 16.7%), gain efficiency (ADG:DMI; 9.4%), and estimated dietary net energy for maintenance (NEm, 8.6%) and gain (NEg, 9.7%). Increasing LW at first implanting decreased overall DMI (linear effect; P = .01), but did not affect overall ADG (P = .17) or gain efficiency (P = .32). Within the range of 267–321 kg, weight at first implanting did not affect growth-performance or carcass characteristics. Interval growth performance of implanted and non-implanted calves was a predictable function of LW.

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1. Introduction

Calf-fed Holstein steers enter the feedlot at characteristically light weights (115–180 kg), where they are fed for periods typically in excess of 300 days (Zinn et al. 2005; Duff & McMurphy 2007). As with beef breeds, application of growth implants is among the most important management tools for enhancement of ADG, gain efficiency, carcass weights, and longissimus muscle area (LMA) of Holstein steers (Chester-Jones et al. 1990; Perry et al. 1991; Zinn et al. 1999). However, the optimal weight at first implant application has received limited research attention. Beckett and Algeo (2002) observed that growth performance of calf-fed Holstein steers (initial weight 156 kg) was not negatively impacted by delaying first implant application until calves had been on feed 120 d. The objective of the present study was to evaluate the weight of calves at first implant application on growth-performance and carcass characteristics of calf-fed Holstein steers.

2. Materials and methods

2.1. Animals processing, housing, and feeding

Ninety-six calf-fed Holstein steers (264 ± 3 kg) were used in a 224-d feeding trial, to evaluate the effects of weight at first implanting on growth performance, and carcass traits of calf-fed Holstein steers. Average daily minimum and maximum air temperature and relative humidity during the trial were was 9.5 and 27.6°C, and 42%, respectively. Upon arrival, steers were vaccinated for IBR-Pl3 (T5V-2, Zoetis, Florham Park, NJ), clostridial-haemophilus (Ultrabac 7, Zoetis, Florham Park, NJ), pastuereilla hemolytic (One Shot, Zoetis, Florham Park, NJ), treated for internal and external parasites (Dectomax, Zoetis, Florham Park, NJ), injected with 500,000 IU of vitamin A (Vitajec A&D 500, RXV Products, Porterville, CA), branded and ear-tagged. Calves were grouped by weight into four weight blocks of four pens each (six calves per pen). Pens were 50 m² with 26.7 m² overhead shade, equipped with automatic drinkers, and 4.3 m fence-line feed bunks. Treatments were: (1) control (not implanted); (2) first implanted at 267 kg live weight (LW) (I-267); (3) first implanted at 291 kg LW (I-291); and (4) first implanted at 321 kg LW (I-321). All implanted cattle were re-implanted on d-112 of trial. Both the initial and final implant was Revalor-S (containing 120 mg of trenbolone acetate and 24 mg of oestradiol; Merck & Co. Inc., Millsboro, DE). Composition of the growing-finishing diet is shown in Table 1. Calves were provided ad libitum access to feed and water. Fresh feed was added to the feed bunk twice daily. Measures of LW and hip height (HH, cm) were obtained at 28-d intervals. HH was measured from the ileum tuber coxae to the floor of the chute, using a metal ruler with a mobile crossbar. For calculation of growth performance, initial LW is the off-truck arrival weight. Interim and final LW were reduced 4% to account for digestive tract fill. Final weights were adjusted to a constant dressing percentage (final LW = carcass weight/0.623).

2.2. Estimation of dietary NE

Energy gain (EG, Mcal/d) was derived from measures of LW (kg) and ADG (kg/d) according to the equation: EG = (0.0557 W0.75)
ADG\(^{1,0.97}\) (NRC 1984). Net energy content of the diet for maintenance and gain were calculated by assuming a constant maintenance energy (EM, Mcal/d) cost of 0.084W\(^{0.75}\) (NRC 2000). The NE values of the diets for maintenance and gain were obtained by means of the quadratic formula: NE\(_m\), Mcal/kg = \((-b \pm \sqrt{b^2 - 4ac})/2c\) (Zinn & Shen 1998), where \(a = -0.877\text{DMI}, b = 0.877\text{EM} + 0.41\text{DMI} + \text{EG}, c = -0.41\text{EM}, \) and NE\(_g\) = 0.877NE\(_m\) - 0.41.

### 2.3. Carcass data

Hot carcasses weights were obtained at time of slaughter. After carcasses chilled for 48 h, the following measurements were obtained: (1) LM area, by direct grid reading of the muscle at the 12th rib; (2) subcutaneous fat over the eye muscle at the 12th rib; (3) kidney, pelvic and heart fat (KPH) as a percentage of HCW; and (4) marbling score (USDA 1965; using 3.0 as minimum slight, 4.0 as minimum small, etc.).

### 2.4. Statistical design and analysis

The trial was analysed as a randomized complete block design, using pen as the experimental unit. Treatments effects were tested using the following orthogonal contrasts: (1) Control (non-implanted) vs. I-267, I-291, and I-321; (2) Linear effect of LW at first implant and (3) Quadratic effect of LW at first implant. Data for WT, and HH traits were analysed using the MIXED procedure of SAS System (SAS Inst. Inc., Cary, NC) as a repeated measures analysis, to allow for heterogeneous variances and correlations among different time intervals on test (Littell et al. 1998). The linear mixed model used for this analysis includes the overall mean, treatment, day, and treatment with day interaction as fixed effects and pen, pen by treatment, and steers within pen by treatment as random components. Estimation was carried out using the method of REML, assuming a variance–covariance structure and correlations over time on the test. The variance–covariance components were subjected to a test of hypothesis using the option COVTEST. The resulting covariance between random parameters was different from zero \(P < .01\). Therefore, different variance–covariance structures were used in TYPE option of REPEATED statement. Final structure was selected based on values closest to zero for the Akaike’s and Schwarz’s Bayesian information criteria. Least square means for treatment, days and interaction effects were used in multiple comparison and significance was declared at \(P < .05\), unless otherwise. To test hypothesis about parallel trends over time for the treatments, day effect as linear and quadratic regression was introduced into linear mixed model, looking for statistical evidence of treatment by day interaction. Full models containing quadratic regression were reduced by removing factors that did not contribute significantly to the model. Hypothesis for equal regressions was realized. Also, one prediction equation for WT trait was obtained by inclusion of HH traits plus interactions and determining best fit applying coefficient of determination \(R^2\), MSE and Mallow’s coefficient \(C(p)\) criterions via the STEPWISE option of REG procedure.

Procedures for animal care and management were conducted under protocols approved by the University of California, Animal Use and Care Advisory Committee.

### 3. Results and discussion

Treatments effect on growth performance of calf-fed Holstein steers are presented in Table 2. Compared with non-implanted controls, implanting improved \(P < .01\) overall 224-d DMI (5.9%), ADG (16.7%), gain efficiency (ADG:DMI; 9.4%), and estimated dietary NE\(_m\) (8.6%) and NE\(_g\) (9.7%). These results are consistent with previous studies involving calf-fed Holstein steers, wherein implanting improved ADG by 12–18%, and gain efficiency by 7–12% (Chester-Jones et al. 1990; Perry et al. 1991; Zinn et al. 1999). Likewise, Ainslie et al. (1992) observed that compared with non-implanted steers, implanting Holstein steers enhanced estimated NE\(_m\) and NE\(_g\) (8.7 and 11.1%, respectively). They imputed this improvement to a 22% reduction in energy requirements for maintenance. Alternatively, the improved apparent dietary NE for implanted steers may be a reflection of the non-nutritional action of implants on composition of gain, enhancing net protein retention, and hence, leaner-than-expected tissue growth for the specified LW and ADG (Reinhart 2007).

Increasing LW at first implanting decreased overall DMI (linear effect; \(P = .01\), but did not affect overall ADG (\(P = .17\)) or gain efficiency (\(P = .32\)). Beckett and Algeo (2002) likewise observed that delaying implanting during the initial and growing phase did not influence overall growth-performance of calf-fed Holstein steers. However, very little work has been reported evaluating the limiting initial weight or weight range when the initial implant might be applied before overall growth-performance is impacted. In the present study, growth-performance response was numerically optimal in steers receiving their first implant at an average weight of 291 kg.

The relationship between average LW and ADG as affected by implant treatments is shown in Figure 1. Daily weight gain of both implanted and non-implanted steers was maximal as steers approached an average weight of approximately

| Table 1. Ingredient composition of diet fed to Holstein steers calves. |
|-----------------------------|---------|-----------------------------|
| Ingredient composition (%) | DM basis |
| Alfalfa                     | 7.64    |
| Sudangrass hay              | 3.86    |
| Steam-flaked corn           | 77.30   |
| Cane molasses               | 4.72    |
| Yellow grease               | 3.10    |
| Limestone                   | 1.30    |
| Urea                        | 0.98    |
| Dicalcium phosphate         | 0.54    |
| Trace mineral salt\(^a\)    | 0.36    |
| Magnesium oxide             | 0.14    |
| Laidomyclin                 | 0.10    |
| Nutrient composition (DM basis)\(^b\) |         |
| NE (Mcal/kg)                | 2.25    |
| Maintenance                 | 1.56    |
| Gain                        | 12.58   |
| Crude protein (%)           | 0.82    |
| Phosphorus (%)              | 0.37    |

\(^a\)Trace mineral salt contained: CoSO\(_4\), 0.068%; CuSO\(_4\), 1.04%; FeSO\(_4\), 3.57%; ZnO, 1.24%; MnSO\(_4\), 1.07%; KI, 0.052%; and NaCl, 92.96%.

\(^b\)Based on tabular values for individual feed ingredients (NRC 2000), with the exception of supplemental fat, which was assigned NE\(_m\) and NE\(_g\) values of 6.00 and 4.50, respectively.
Table 2. Effects of LW at first implant application on growth performance and dietary energetics of calf-fed Holstein steers on entire period of growing-finishing (224-d).

| Item                          | Control | 267 | 291 | 321 | SEM | Implant vs. non-implant | Contrast P-value |
|------------------------------|---------|-----|-----|-----|-----|-------------------------|-----------------|
| Pen replicates               | 4       | 4   | 4   | 4   |     |                         |                 |
| LW (kg)                      |         |     |     |     |     |                         |                 |
| Initial                      | 263.8   | 266.8 | 264.3 | 263.3 | 1.6  | 0.60                    | .15 .69         |
| Final                        | 548.7   | 604.9 | 601.1 | 589.4 | 5.7  | <0.01                   | .09 .59         |
| ADG (kg/d)                   | 1.28    | 1.51 | 1.51 | 1.46 | 0.03 | <0.01                   | .17 .48         |
| DMI (kg/d)                   | 7.75    | 8.41 | 8.19 | 8.02 | 0.09 | <0.01                   | .01 .85         |
| Gain to feed                 | 0.165   | 0.180 | 0.184 | 0.182 | 0.003 | <0.01                  | .69 .32         |
| Diet net energy (Mcal/kg)    |         |     |     |     |     |                         |                 |
| Maintenance                  | 2.21    | 2.37 | 2.41 | 2.38 | 0.02 | <0.01                   | .73 .29         |
| Gain                         | 1.53    | 1.67 | 1.70 | 1.68 | 0.02 | <0.01                   | .73 .29         |
| Observed/expected diet NE (Mcal/kg) |       |     |     |     |     |                         |                 |
| Maintenance                  | 0.97    | 1.04 | 1.06 | 1.05 | 0.01 | <0.01                   | .73 .29         |
| Gain                         | 0.97    | 1.05 | 1.08 | 1.06 | 0.01 | <0.01                   | .73 .29         |

aControl = non-implanted; LW at first implant. All implant treatments were re-implanted on d-112 of trial.
bInitial off-truck arrival weight.
cCarcass adjusted final weight (hot carcass weight/0.623, decimal fraction of average dressing percentage).

370 kg, averaging 1.76 and 1.50 kg/d, respectively. From roughly 370 kg until harvest (598 kg), ADG of implanted steers was similar ($P > .10$). Daily weight gain of non-implanted steers decreased markedly after steers reached an average shrunk weight of 510 kg. A comparable marked decline in ADG occurred in implanted steers as they reached a shrunk weight of approximately 550 kg. As a function of average shrunk weight (AW, kg), incremental ADG, kg can be explained by the equations:

Implanted steers ADG = $1.242 - 0.003278AW + 0.0000264AW^2 - 0.0000002964AW^3$ ($r^2 = .80$),
Non - implanted steers ADG = $1.183 - 0.002247AW + 0.00001837AW^2 - 0.0000002824AW^3$ ($r^2 = .80$).

The relationship between AW and DMI as affected by dietary treatments is shown in Figure 2. Daily DMI of non-implanted steers was maximal as steers approached an AW of approximately 510 kg. In the case of implanted steers, daily DMI was maximal as steers approached an AW of approximately 548 kg. Thereafter, daily DMI began a decline. As a function of AW, incremental DMI, kg/d can be explained by the equations:

Implanted steers DMI, kg/d = $4.5939 - 0.03019AW + 0.000141208AW^2 - 0.000000139AW^3$ ($P < .01, r^2 = .99$),
Non - implanted steers DMI, kg/d = $19.925 - 0.13977AW + 0.000437895AW^2 - 0.000000408AW^3$ ($P < .01, r^2 = .98$).

As can be seen from the above two equations, average shrunk weight, alone, does a very good job of explaining DMI. However, the practicality of their use is limited as they do not incorporate differences in dietary NE and ADG. Conventionally, DMI may be also predicted as a function of LW, ADG, and NE value of the diet according to the relationship:

$$ \text{DMI, kg/d} = \frac{(0.084 \times \text{LW}^{0.75})}{2.25} + \frac{(0.077 \times \text{LW}^{0.75} \times \text{ADG}^{1.097})}{1.56}, $$

where 0.084 is the assumed maintenance coefficient for Table 2.

Table 2. Effects of LW at first implant application on growth performance and dietary energetics of calf-fed Holstein steers on entire period of growing-finishing (224-d).

| Item                          | Control | 267 | 291 | 321 | SEM | Implant vs. non-implant | Contrast P-value |
|------------------------------|---------|-----|-----|-----|-----|-------------------------|-----------------|
| Pen replicates               | 4       | 4   | 4   | 4   |     |                         |                 |
| LW (kg)                      |         |     |     |     |     |                         |                 |
| Initial                      | 263.8   | 266.8 | 264.3 | 263.3 | 1.6  | 0.60                    | .15 .69         |
| Final                        | 548.7   | 604.9 | 601.1 | 589.4 | 5.7  | <0.01                   | .09 .59         |
| ADG (kg/d)                   | 1.28    | 1.51 | 1.51 | 1.46 | 0.03 | <0.01                   | .17 .48         |
| DMI (kg/d)                   | 7.75    | 8.41 | 8.19 | 8.02 | 0.09 | <0.01                   | .01 .85         |
| Gain to feed                 | 0.165   | 0.180 | 0.184 | 0.182 | 0.003 | <0.01                  | .69 .32         |
| Diet net energy (Mcal/kg)    |         |     |     |     |     |                         |                 |
| Maintenance                  | 2.21    | 2.37 | 2.41 | 2.38 | 0.02 | <0.01                   | .73 .29         |
| Gain                         | 1.53    | 1.67 | 1.70 | 1.68 | 0.02 | <0.01                   | .73 .29         |
| Observed/expected diet NE (Mcal/kg) |       |     |     |     |     |                         |                 |
| Maintenance                  | 0.97    | 1.04 | 1.06 | 1.05 | 0.01 | <0.01                   | .73 .29         |
| Gain                         | 0.97    | 1.05 | 1.08 | 1.06 | 0.01 | <0.01                   | .73 .29         |

*Control = non-implanted; LW at first implant. All implant treatments were re-implanted on d-112 of trial.

aInitial off-truck arrival weight.

bCarcass adjusted final weight (hot carcass weight/0.623, decimal fraction of average dressing percentage).

370 kg, averaging 1.76 and 1.50 kg/d, respectively. From roughly 370 kg until harvest (598 kg), ADG of implanted steers was similar ($P > .10$). Daily weight gain of non-implanted steers decreased markedly after steers reached an average shrunk weight of 510 kg. A comparable marked decline in ADG occurred in implanted steers as they reached a shrunk weight of approximately 550 kg. As a function of average shrunk weight (AW, kg), incremental ADG, kg can be explained by the equations:

Implanted steers ADG = $1.242 - 0.003278AW + 0.0000264AW^2 - 0.0000002964AW^3$ ($r^2 = .80$),
Non - implanted steers ADG = $1.183 - 0.002247AW + 0.00001837AW^2 - 0.0000002824AW^3$ ($r^2 = .80$).

The relationship between AW and DMI as affected by dietary treatments is shown in Figure 2. Daily DMI of non-implanted steers was maximal as steers approached an AW of approximately 470 kg. In the case of implanted steers, daily DMI was maximal as steers approached an AW of approximately 548 kg. Thereafter, daily DMI began a decline. As a function of AW, incremental DMI, kg/d can be explained by the equations:

Implanted steers DMI, kg/d = $4.026 - 0.012223AW + 0.0000967AW^2 - 0.000000103AW^3$ ($P < .01, r^2 = .99$),
Non - implanted steers DMI, kg/d = $19.93 - 0.13977AW + 0.000437895AW^2 - 0.000000408AW^3$ ($P < .01, r^2 = .98$).

As can be seen from the above two equations, average shrunk weight, alone, does a very good job of explaining DMI. However, the practicality of their use is limited as they do not incorporate differences in dietary NE and ADG. Conventionally, DMI may be also predicted as a function of LW, ADG, and NE value of the diet according to the relationship:

$$ \text{DMI, kg/d} = \frac{(0.084 \times \text{LW}^{0.75})}{2.25} + \frac{(0.077 \times \text{LW}^{0.75} \times \text{ADG}^{1.097})}{1.56}, $$

where 0.084 is the assumed maintenance coefficient for
Holstein steers, and 2.25 and 1.56 are the expected NE values of the diet for maintenance and gain, respectively (NRC 1984; Table 1). This relationship was not derived experimentally. Rather, it assumes that EG for calf-fed Holstein steer calves is similar to that of medium-frame beef steer calves (0.077 LW^{0.75} ADG^{1.097}; NRC 1984), and that the maintenance requirement for Holstein steers is 9% greater (0.084 vs. 0.077; Garrett 1971). The relationship between observed and predicted DMI using this approach are:

Non-implanted steers predicted DMI, kg/d = - 0.871
+ 1.098 observed DMI, \( r^2 = .82 \),

Implanted steers predicted DMI, kg/d = - 0.210
+ 1.096 observed DMI, \( r^2 = .81 \).

For implanted and non-implanted steers, the ratio of predicted:observed DMI averaged 1.06 ± 0.08 and 0.98 ± 0.06, respectively. With implanted steers, the conventional equation consistently overestimated DMI across the range of LW, whereas with non-implanted steers, DMI was largely underestimated. Although application of this conventional approach has yielded consistent results for calf-fed Holstein steers with respect to overall average observed vs. expected dietary NE yields, consistent results for calf-fed Holsteins. Rather, it assumes that EG for calf-fed Holstein steer calves is similar to that of medium-frame beef steer calves (0.077 LW^{0.75} ADG^{1.097}; NRC 1984), and that the maintenance requirement for Holstein steers is 9% greater (0.084 vs. 0.077; Garrett 1971). The relationship between observed and predicted DMI using this approach are:

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Implanted steers predicted DMI, kg/d = - 0.210
+ 1.096 observed DMI, \( r^2 = .81 \).

For implanted and non-implanted steers, the ratio of predicted:observed DMI averaged 1.00 ± 0.03 and 1.00 ± 0.03, respectively. Although application of this conventional approach has yielded consistent results for calf-fed Holstein steers with respect to overall average observed vs. expected dietary NE yields, consistent results for calf-fed Holsteins. Rather, it assumes that EG for calf-fed Holstein steer calves is similar to that of medium-frame beef steer calves (0.077 LW^{0.75} ADG^{1.097}; NRC 1984), and that the maintenance requirement for Holstein steers is 9% greater (0.084 vs. 0.077; Garrett 1971). The relationship between observed and predicted DMI using this approach are:

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Implanted steers predicted DMI, kg/d = - 0.210
+ 1.096 observed DMI, \( r^2 = .81 \).
As mentioned previously, overall gain efficiency was not different among implanted groups. This effect was due to a compensating increase in gain efficiency, particularly noticeable during the final 28 days on feed (linear effect, \( P < .01 \)). It is expected that relative performance response to growth implants declines with time post-implantation (Montgomery et al. 2001). Reinhardt (2007) observed that re-implanting cattle around d 70 during these declines boosted performance response to a level equal to or greater than that of the previous implant. In the present study, treatments I-291 and I-321 were re-implanted at 84 and 56 d following the initial implant.

Consistent with Schlegel et al. (2006), HH was a good predictor of LW in Holstein calves. For non-implanted calves, HH explained 77% of the variation in LW. For calves first implanted at an average weight of 267, 291, and 321 kg, HH explained 82%, 83%, and 84%, respectively, of the variation in LW. The close relationship between LW and LW:HH ratio of non-implanted and implanted steers is shown in Figure 4. As LW increases, LW:HH ratio linearly increases (LW:HH, kg/cm = 0.405 + 0.00607LW, \( r^2 = .997 \)). Consistent with Solis et al. (1989), implanting enhances muscularity largely to the extent that final LW of implanted steers is greater than that of non-implanted steers, allowing for greater LW:HH ratio.

Table 3. Effects of LW at first implant application on carcass characteristics of calf-fed Holstein steers

| Item                        | Control 267 | 291 | 321 | SEM | Implant vs. non-implant | Contrast P-value |
|-----------------------------|-------------|-----|-----|-----|-------------------------|------------------|
| Carcass weight (kg)         | 342.4       | 375.2 | 376.3 | 366.3 | 4.1                     | <0.01            |
| Dressing (%)                | 62.41       | 62.03 | 62.61 | 62.15 | 0.4                     | 0.72             |
| LMA (cm²)                   | 73.68       | 81.22 | 80.57 | 80.67 | 1.7                     | <0.01            |
| Fat thickness (cm)          | 1.23        | 1.09  | 1.09  | 1.19  | 0.09                    | 0.35             |
| KPH fat (%)                 | 2.35        | 2.17  | 1.93  | 2.10  | 0.12                    | 0.08             |
| Yield grade (%)             | 50.0        | 50.5  | 50.4  | 50.4  | 0.28                    | 0.21             |
| Marbling score\(^a\)        | 5.47        | 5.16  | 4.81  | 5.03  | 0.27                    | 0.17             |

\(^a\)Control = non-implanted; LW at first implant. All implant treatments were re-implanted on d-112 of trial.

\(^b\)Kidney, pelvic and heart fat as a percentage of carcass weight.

\(^c\)Coded: minimum slight = 3, minimum small = 4, etc.

**4. Implications**

Application of growth implants in calf-fed Holstein steers has marked positive effects on daily weight gain, gain efficiency, carcass weight and LMA. Within the range of 267–321 kg, weight at first implanting did not affect growth-performance or carcass characteristics. Interval growth performance of implanted and non-implanted calves is a predictable function of LW.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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