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Impacts of economic factors influencing net returns of beef feedlot heifers administered two implant programs and fed for differing days-on-feed from pooled randomized controlled trials

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Abstract

The objective of this research was to evaluate the effects of two implant programs and differing days-on-feed (DOF) on net returns of beef feedlot heifers using sensitivity analyses of key economic factors. Crossbred beef heifers [*n* = 10,583; initial weight 315 kg (± 20.1 SD)] were enrolled across three trials (one Kansas, two Texas feedlot trials). Heifers were blocked by arrival and randomly allocated to one of six pens, resulting in a total of 144 pens and 24 blocks. Pen was randomly assigned to treatment as a 2 × 3 factorial. Implant programs were: IH + 200—Revalor-IH at initial processing, and a terminal implant after approximately 90 DOF (Revalor-200), or, XH—a single implant at initial processing (Revalor-XH). The DOF treatments were: heifers fed to a standard baseline endpoint (BASE) or heifers fed for an additional + 21 or + 42 d beyond BASE. Pen-level partial budgets were used for economic sensitivity analyses, which varied price points of single pricing components with all other components fixed. Variable components were live-fed cattle prices, base carcass prices (i.e., dressed), Choice-Select spread (CS-spread), and feed and yardage prices (FYP). For each, a Low, Mid-Low, Middle, Mid-High, and High price was chosen. Linear mixed models were fit for statistical analyses ($\alpha = 0.05$). There were no significant two-way interactions (*P*-values ≥ 0.14). Regardless of the variable component evaluated, XH heifers had poorer net returns than IH + 200 at all prices ($P \leq 0.04$). Selling live, the + 21 and (or) + 42 heifers had lower net returns than BASE at every fed cattle price point ($P < 0.01$). Selling dressed, the + 21 and (or) + 42 heifers had lower returns than BASE at Low, Mid-Low, and Middle fed cattle base prices ($P < 0.01$); there were no significant DOF differences at Mid-High, or High prices ($P \geq 0.24$). Net returns were lower for + 42 than BASE at all CS-spreads ($P \leq 0.03$), while BASE and + 21 did not differ significantly. Longer DOF had lower net returns than BASE when selling live at every FYP ($P < 0.01$) except at the Low price ($P = 0.14$). Selling dressed, there was no significant effect of DOF at Low or Mid-Low FYP ($P \geq 0.11$); conversely, extended DOF had lower net returns than BASE at Middle, Mid-High, and High FYP ($P < 0.01$). Overall, there was minimal economic evidence to support extending feedlot heifer DOF beyond the BASE endpoint, and when feeding longer, larger reductions in return were observed when marketing live as opposed to dressed.

Lay Summary

In the United States, feedlot cattle are spending more time on feed and finishing with heavier weights than in past decades. With this comes increased costs, as well as performance and carcass compositional changes leading to economic implications. Key economic factors including feed and cattle sale prices may have differing impacts on the economic implications of longer feeding and alternative implant programs, depending on their price levels. This dynamic was evaluated for beef feedlot heifers with randomized controlled trial data. Heifers that received two implants during the finishing period had consistently higher economic returns compared to those receiving a single, extended-release implant. Despite recent industry trends, there was minimal evidence to support feeding heifers longer than a feedlot standard endpoint. When using low cattle sale prices, net returns were reduced for longer fed heifers compared to the standard endpoint; as prices increased, returns became closer to the standard. Estimated net returns for longer fed heifers became poorer compared to the standard endpoint as feed prices increased. Compared to the feedlot standard, positive net return estimates for longer fed heifers occurred only when marketing on a carcass basis, and losses were less severe when marketing on a carcass basis as opposed to live.

Key words: days-on-feed, economics, feedlot, heifers, implant, net return

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Introduction

In recent years, feedlot cattle have progressively been fed to heavier endpoints (LM_CT150; USDA-AMS). The use of hormonal and steroidal implants has aided in production efficiency improvements (Reinhardt and Wagner, 2014; Smith and Johnson, 2020) that enable greater finished weights. Use of various implants and (or) extending days-on-feed (DOF) in the feedlot for both steers and heifers has received considerable past research (Herschler et al., 1995; Sissom et al., 2007; Parr et al., 2011; Rathmann et al., 2012; Reinhardt and Wagner, 2014; Hilscher et al., 2016; Smith et al., 2019, 2020; Ohnoutka et al., 2021; Word et al., 2021; Horton et al., 2022). However, while most prior studies mention economic importance or implications, none (to the knowledge of the authors) have performed a concurrent economic analysis. Economics as a measurable (or estimable) outcome is a critical factor for decision-making by industry stakeholders (Cernicchiaro et al., 2022; Dewsbury et al., 2022). As is often the case, economic incentive may be required for producer-level change to occur for any treatment intervention or management practice.

Horton et al. (2022) evaluated feedlot performance and carcass characteristics of beef feedlot heifers administered 2 alternative implant programs and fed for differing DOF with pooled data from 3 randomized controlled trials. The implant programs had significant impacts on live feed efficiency, as well as hot carcass weight (HCW) and dressed yield, which were accompanied by shifts in the distributions of US Department of Agriculture (USDA) Quality Grades (QG) and Yield Grades (YG). Heifers fed for longer DOF than a common endpoint had linear increases in final body weight (BW) but had reduced average daily gain (ADG) and feed efficiency. From a carcass standpoint, longer-fed heifers had heavier HCW, higher dressed yields, and shifted carcass grades toward higher QG and YG (i.e., heavier, fatter carcasses with more intramuscular fat). Taken together, controlled trials with treatment factors incorporating a serial harvest component may have substantial economic impacts due to the alterations in production outcomes, which have not been well quantified by peer-reviewed literature. There may be differing implications when considering alternative marketing strategies (i.e., live vs carcass sales); additionally, carcass-based cattle sales may incorporate premiums and discounts (a "grid") for value-based carcass pricing.

Due to changes in both live performance and carcass characteristics, alternative treatment factors may result in varied economic returns. Pen-level economic outcomes are also affected by varying market conditions, resulting in alternative management decisions being economically optimal at different times. Mark et al. (2000) estimated that fed cattle price was the most influential factor on feedlot cattle profit, followed by feeder cattle and corn prices. From an experimental trial perspective, feeder cattle prices are of lesser consequence as they are a "sunk" cost that should not vary amongst well randomized treatment groups. With these observations in mind, it was desirable to perform analyses evaluating differing fed cattle prices, feed prices, and premiums and discounts for QG under live and dressed (i.e., carcass) sales scenarios, in order to generate a more robust economic assessment. In economics, sensitivity analysis is a method to evaluate "risk" when there is uncertainty regarding input and output prices, as well as when there may be variability in output quantities (Rushton, 2007). Risk may be defined differently across disciplines; in this case, risk is characterized as uncertainty pertaining to deviation(s) from expectations and potential financial loss and is inherent in any investment decision. In general, people are considered to be risk-averse, meaning that they are cautious when decision-making and often forego additional income or increase their costs in order to avert risk (Rushton, 2007). In economic sensitivity analyses, a range of possible prices for parameters that have high influence and (or) uncertainty are evaluated for their impact on an outcome variable. Producers and other stakeholders can use the output of sensitivity analyses to monitor key variables, based on how sensitive an outcome is to changes in the variables (Rushton, 2007). For this research, the outcome variable of interest is net return. To summarize, sensitivity analyses would provide stakeholders with the estimated impact and implications of individual pricing components on economic returns. Using the randomized controlled trial data described by Horton et al. (2022), the primary objective was to evaluate the effects of alternative implant programs and differing DOF on net returns of beef feedlot heifers, along with the impact of varying key economic factors using sensitivity analyses. A secondary objective was to evaluate the effects of treatments on net grid revenue adjustments from carcass-based premiums and discounts.

Materials and Methods

Background

Data used for economic sensitivity analyses are from pooled clinical trials, for which feedlot performance and carcass characteristics have been previously summarized by Horton et al. (2022). In brief, three commercial trials were conducted with identical treatment and design structures, making them compatible for pooled analyses. The trials had a 2 × 3 factorial treatment structure in a randomized complete block design. The treatment factors included two implant programs and three differing DOF.

Implant programs were: IH + 200, where heifers received an implant at initial processing (Revalor-IH; Merck Animal Health, Lenexa, KS) containing 80 mg trenbolone acetate (TBA) and 8 mg estradiol (E_2), and were later removed from their home pens after approximately 90 DOF and re-implanted with a terminal implant containing 200 mg TBA and 20 mg E_2 (Revalor-200; Merck Animal Health); or, XH, a single, extended-release implant (Revalor-XH; Merck Animal Health) containing a total of 200 mg TBA and 20 mg E_2 administered at initial processing. Revalor-XH contains both uncoated (80 mg TBA and 8 mg E_2) and coated (120 mg TBA and 12 mg E_2) components; the uncoated pellets ($n = 4$) degrade and have immediate bioavailability of anabolic steroid hormones to the animal, whereas the outer layer of the coated pellets ($n = 6$) begins to degrade after approximately 70 d and the remaining steroid hormones are gradually released thereafter. Revalor-IH and Revalor-200 are uncoated implants that have immediate bioavailability after administration, but therefore have a shorter effective duration.

Days-on-feed treatments were BASE, heifers fed to a baseline endpoint as determined by feedlot marketing groups (i.e., the time-point or degree of finish where heifers were normally harvested in the feedlots); + 21, heifers fed an additional 21 d beyond BASE pens (within block); and + 42, heifers fed an additional 42 d beyond BASE pens (within block).

The 2 Texas trials have been described independently (Smith et al., 2019; experiments 1 and 2) as has the Kansas trial (Horton et al., 2022). In Smith et al. (2019), experiment 1, there were 3,780 crossbred beef heifers [mean initial BW 309 ± 6.4 kg (1 SD)] that were enrolled in the summer of 2015 in nine blocks with a total of 54 pens (70 animals per pen), and had a mean BASE DOF of 172 ± 4.4 (1 SD). Smith et al. (2019), experiment 2, used 3,719 crossbred beef heifers [mean initial BW 337 ± 8.9 kg (1 SD)] that were enrolled in the spring of 2018 in nine blocks with a total of 54 pens [mean 69 animals per pen (range 65 to 70)], and had a mean BASE DOF of 152 ± 1.1 (1 SD). In the Kansas trial, 3,084 crossbred beef heifers [mean initial BW 291 ± 8.9 kg (1 SD)] were enrolled in December of 2018 in 6 blocks with a total of 36 pens [mean 86 animals per pen (range 74 to 115)] and had a mean BASE DOF of 179 ± 4.7 (1 SD). For additional detail on the individual trials (e.g., allocation, cattle management, dietary formulations), see Smith et al. (2019) and Horton et al. (2022).

Sensitivity analyses

A partial budget approach was used to conduct sensitivity analyses for economic factors, to evaluate how individual pricing components affect net returns of beef feedlot heifers subjected to the experimental treatments. Sensitivity analyses were conducted by varying one component (e.g., fed cattle price) while holding all other components in the partial budget(s) constant. Two mechanisms are commonly used for fed cattle sales in the US; these are a live sale basis (live weight multiplied by live fed cattle price) and a dressed sale basis (carcass weight multiplied by dressed fed cattle price), where "dressed" and "carcass" are synonymous. Both scenarios were considered in this analysis. The pricing components varied in sensitivity analyses were fed cattle price [live price for live weight sales, dressed base price for carcass weight sales accounting for carcass quality-based premiums and discounts (a "grid")], the Choice-Select spread (CS-spread), and feed and yardage price (FYP). Pricing components that were held constant were feeder cattle purchase price, initial processing charge, implant charge (accounting for the difference between XH and IH + 200 protocols), animal morbidity, animal mortality (rendering cost), interest, and opportunity cost which accounts for the cost of waiting additional days beyond BASE to market cattle. Fixed prices for revenue sources were a fixed grid for YG and weight-based [under 249 kg (550 lb) and over 476 kg (1,050 lb)] premiums and discounts under the dressed (i.e., carcass) sale basis scenario, and revenue from culled animals removed from the trials for health reasons.

Reported prices from January 2017 through December 2022 were sourced for the selection of price points for variable components in the sensitivity analyses. For each variable component, five price points were selected for evaluation and were categorized as a Low, Mid-Low, Middle, Mid-High, or High price over the date range. The minimum and maximum values for each variable component that occurred in the date range (from weekly or monthly prices) were used to determine Low and High price points. It was preferable to use whole numbers that are easy to interpret and would result in equal intervals for the chosen prices; therefore, the numbers closest to the minimum and maximum of each component which would achieve this were utilized. For example, the minimum weekly live-fed cattle price (2017 through 2022) was $95.14/cwt (cwt = 100 lb = 45.4 kg), and the maximum was $156.80/cwt (LM_CT150; USDA-AMS); therefore, $95.00/cwt was selected for the Low price, and $155.00/cwt was selected for the High price, creating equal intervals of 110.00, 125.00, and 140.00 $/cwt for Mid-Low, Middle, and Mid-High prices, respectively. Consequently, the Middle price is not necessarily near the mean or median price for a given component within the date range; it is simply a moderate value located approximately at the center of the most extreme observed prices. This process was repeated for monthly Central Plains FYP (CattleFax), and weekly CS-spread (LM_CT169; USDA-AMS). The one exception for price selection was for dressed-fed cattle base prices, where the base price was determined by dividing each live-fed cattle price point by a fixed dressed yield of 0.639, the mean dressing percent (63.9%) of BASE heifers (Horton et al., 2022), and rounding the result to the nearest whole number. This was done so the implied dressing percent difference between live and dressed-fed cattle prices would be equivalent between price points. The result was dressed-fed cattle base prices of 149.00, 172.00, 196.00, 219.00, and 243.00 $/cwt for Low, Mid-Low, Middle, Mid-High, and High prices, respectively. Selected price points for FYP were 230.00, 275.00, 320.00, 365.00, and 410.00 $/907 kg [1 US ton (2,000 lb)] dry matter (DM) for Low, Mid-Low, Middle, Mid-High, and High prices, respectively.

The LM_CT169 USDA-AMS 5 Area Weekly Slaughter Cattle—Premiums and Discounts report sets Choice as the base category for QG therefore the CS-spread was the Select discount. Chosen price points for Select discounts were −5.00, −10.00, −15.00, −20.00, and −25.00 $/cwt for Low, Mid-Low, Middle, Mid-High, and High spreads, respectively. Other QG included in the grid were Prime and sub-Select; the discount for Standard grades was used for all carcasses that graded sub-Select. While the objective was to evaluate the CS-spread, Prime, and sub-Select prices were allowed to fluctuate along with Choice and Select grades. To calculate prices for Prime premiums and sub-Select discounts for each CS-spread price point, two linear regression models were used. Data used for the models were the same as sourced for price determination above of weekly reported prices from 2017 through 2022. For each model, the Select discount, and a quadratic term for Select discount were the independent variables, and Prime premium or Standard discount was the dependent variable. The resulting coefficients and SE from the regression equation for estimation of Prime premiums was:

$$\text{Prime premium} = 15.799 + 0.482\text{Select discount} + 0.027(\text{Select discount})^2 \\ \pm \text{SE} = (1.403)(0.199)(0.006) \quad (1)$$

For equation (1), Select discount and (Select discount)^2 were significant ($P = 0.02$ and $P < 0.01$, respectively), RMSE = 5.37, and $R^2 = 0.24$.

The coefficients and SE from the regression equation for estimation of Standard discounts was:

$$\text{Standard discount} = -16.042 + 0.985\text{Select discount} + 0.006(\text{Select discount})^2 \\ \pm \text{SE} = (0.349)(0.049)(0.002) \quad (2)$$

For equation (2), Select discount and (Select discount)^2 were significant ($P < 0.01$), RMSE = 1.34, and $R^2 = 0.95$.

This resulted in Prime premiums of 14.00, 14.00, 15.00, 17.00, and 21.00 $/cwt for Low, Mid-Low, Middle, Mid-High, and High CS-spreads, respectively. Low and Mid-Low Prime premiums were equivalent due to rounding and the quadratic nature of the relationship. Standard discounts were –21.00, –25.00, –29.00, –33.00, and –37.00 $/cwt for Low, Mid-Low, Middle, Mid-High, and High CS-spreads, respectively.

The sensitivity analyses were conducted by varying a single component, while holding all others constant at either the fixed value for fixed components or at the Middle price point for other variable components. For example, when evaluating each FYP variable price point, the live-fed cattle price was fixed at $125.00/cwt for live cattle sales, and under the dressed sales scenario, the base fed cattle price was fixed at $196.00/cwt and the CS-spread was fixed at $-15.00/cwt. All selected price points of variable components evaluated in sensitivity analyses are in Table 1. Note that rows (variable components) are independent of the columns (price points), in that each column does not represent a set of prices used concurrently; rather, each specific price for any component was evaluated with all others set at the Middle value. The Middle price point column is an exception, as all variable components were implemented at the Middle value.

Partial budgeting

For evaluation, multiple partial budgets were built, one for each price point for each variable component. Partial budgets were applied at the pen-level for all relevant outcomes measured in the trials, regardless of statistical significance reported by Horton et al. (2022). For example, while not statistically significant, morbidity was accounted for in the partial budgets. Net return was defined as the difference between total pen revenue and total pen costs, per animal sold.

Heifer purchase prices were assumed using weekly prices from 2017 through 2022 for medium and large frame #1 feeder heifers from Oklahoma City auctions sourced from the Livestock Marketing and Information Center (LMIC); this is a large market, geographically near trial locations. Trial average initial BW were classified into two different 45.4 kg (100 lb) weight categories; mean initial BW in Smith et al. (2019) experiment 1 and the Kansas trial (Horton et al., 2022) was in the 272 to 317 kg (600 to 699 lb) feeder weight range, while Smith et al. (2019) experiment 2 mean initial BW was in the 318 to 362 kg (700 to 799 lb) feeder weight range. To use the same purchase price across all pens, a weighted mean from reported feeder heifer purchase prices based on the number of pens in each trial was calculated by averaging 272 to 317 kg and 318 to 362 kg feeder heifer price categories. While feeder heifer purchase price was held constant in the budgets, the price was determined similarly to the variable components, where a value reflective of the Middle price over the date range was chosen. To estimate the total pen purchase price, a weighted feeder heifer price of $135.00/cwt was multiplied by the total initial pen weight for each pen.

Processing costs were fixed, with a slight difference between implant programs. A standard processing protocol was assumed for animal health and related products used across the three trials. Products and prices were sourced from PBS Animal Health on March 3, 2022, and dosage to estimate price/animal was calculated based on manufacturer recommendations and a 318 kg animal weight (see Table 2 for additional detail). The initial processing charge including an assumed $1.50/animal chute charge accounting for equipment and labor was $13.25/animal before incorporating costs for implant program treatments. Heifers in the XH

Table 1. Price points selected for partial budget sensitivity analyses from reported prices (2017 through 2022) for evaluation of their impact on estimated net return differences of beef feedlot heifers administered differing implant programs and fed for differing days-on-feed

Variable components	Price point*					Source
	Low	Mid-Low	Middle	Mid-High	High	
Cost						
Feed and yardage price, $/907 kg DM[†]	230.00	275.00	320.00	365.00	410.00	CattleFax, Centennial, CO
Revenue						
Live-fed cattle price[‡], $/cwt	95.00	110.00	125.00	140.00	155.00	LM_CT150 (USDA-AMS)
Dressed base fed cattle price[§], $/cwt	149.00	172.00	196.00	219.00	243.00	LM_CT150 (USDA-AMS)
Choice-Select spread[‖], $/cwt						LM_CT169 (USDA-AMS)
Prime[¶]	14.00	14.00	15.00	17.00	21.00	
Choice	0.00	0.00	0.00	0.00	0.00	
Select	–5.00	–10.00	–15.00	–20.00	–25.00	
Sub-Select**	–21.00	–25.00	–29.00	–33.00	–37.00	

*Price point columns do not represent sets of prices used concurrently, rather, only the specific prices that were selected for each variable component in the leftmost column; sensitivity analyses on a component (e.g., feed and yardage price) varied its prices (Low through High) while holding all others (e.g., live-fed cattle price) constant at the Middle price point.
†907 kg = 1 US ton (2,000 lb); DM = dry matter.
‡5-area negotiated heifer price (live free-on-board; over 80% Choice); cwt = 45.4 kg (100 lb).
§Determined by multiplying the live-fed cattle price by a common dressing percent of 63.9% (the mean dressed yield of control cattle), and rounded to the nearest whole number; cwt = 45.4 kg (100 lb).
‖Choice-Select spread is the difference between Choice premiums and Select discounts, with Choice set to zero (i.e., sensitivity analyses were based on the Select discount); cwt = 45.4 kg (100 lb).
¶Prime premiums were estimated using coefficients from a linear regression model with Prime premium as the dependent variable and Select discount as the explanatory variable from the same set of 2017 through 2022 price data.
**Carcasses graded sub-Select received the discount for Standard grading carcasses; Standard discounts were estimated using coefficients from a linear regression model with Standard discount as the dependent variable and Select discount as the explanatory variable from the same set of 2017 through 2022 price data.

Table 2. Prices used for fixed components that were not varied in partial budget sensitivity analyses

Fixed components	Price	Source
Cost		
Feeder heifer purchase price*, $/cwt	135.00	Livestock Marketing Information Center
Initial processing charge†, $/animal	13.25	Estimated (PBS Animal Health)
Implant charge‡, $/animal	8.34 (IH + 200) or 8.32 (XH)	Estimated (PBS Animal Health)
Morbidity, $/treatment	23.60	USDA-NAHMS (2013)
Mortality§, $/death	40.50	Sparks Companies Inc. (2002); inflation adjusted (US BLS)
Interest and opportunity cost‖, yearly rate (%)	5.85	Ag Credit Survey, Fed. Res. Bank of KS City
Revenue		
Carcass premiums/discounts¶, $/cwt dressed		LM_CT169 (USDA-AMS)
YG 1	5.25	
YG 2	2.50	
YG 3	0.00	
YG 4	−10.00	
YG 5	−14.00	
Under 249 kg discount	−21.50	
Over 476 kg discount	−18.00	
Culled animals**, $/cwt dressed	125.00	LM_CT168 (USDA-AMS), Horton et al. (2021)

*Price for medium and large frame #1 feeder heifers from Oklahoma City auctions using a weighted average price of 272 to 317 kg (600 to 699 lb) and 318 to 362 kg (700 to 799 lb) pricing categories (weighted average based on initial body weight of cattle across the three trials); cwt = 45.4 kg (100 lb).
†Estimated by sourcing prices for individual products from a standardized processing protocol. The products and prices were: a modified-live antiviral vaccine at $4.20/animal (Vista Once; Merck Animal Health, Lenexa, KS), a clostridial vaccine at $0.88/animal (Vision 8; Merck Animal Health), an oral anthelmintic at $1.71/animal (Safeguard; Merck Animal Health), an injectable parasiticide at $2.16/animal (Dectomax; Zoetis Animal Health, Parsippany, NJ), a topical insecticide at $0.81/animal (Clean-up II; Elanco Animal Health, Greenfield, IN), two ear tags for identification at $1.99/animal (ATag; Allflex, Kenilworth, NJ), plus a $1.50/animal chute charge. Sales tax was not accounted for in any of these prices, as they likely overestimate what is actually paid by commercial feedlots that receive discounts and order in bulk.
‡Implant charge for IH + 200 is the sourced price for Revalor-IH at initial processing ($3.08/animal; Merck Animal Health, Lenexa, KS) plus the sourced price for Revalor-200 ($3.75/animal; Merck Animal Health) and an assumed $1.50/animal chute charge for re-implanting; implant charge for XH is the sourced price for Revalor-XH ($8.32/animal; Merck Animal Health) at initial processing only.
§Mortality cost is the estimated cost of rendering a dead animal, inflation adjusted using the US Bureau of Labor and Statistics (US BLS) producer price index from the Sparks Companies Inc. (2002) report.
‖Interest cost was added to total heifer purchase and 1/2 of the total feed and yardage cost as the rate [5.85% × (pen DOF/365)] multiplied by each respective cost. Opportunity cost of waiting additional days (+ 21 or + 42) to market heifers beyond the baseline cattle endpoint (BASE) was estimated using the interest rate; opportunity cost was applied to only + 21 and + 42 pens, which was the interest rate [5.85% × (21 or 42/365)] multiplied by the revenue received by the corresponding BASE treatment pen within each block.
¶YG = USDA Yield Grade; 249 kg = 550 lb; 476 kg = 1,050 lb; cwt = 45.4 kg (100 lb).
**To estimate prices for revenue received from animals removed from the trials, a percentage of the reported dressed Breaker cow (over 227 kg) price (determined by the estimated carcass weight of the animal) was used (Horton et al., 2021); cwt = 45.4 kg (100 lb).

treatment were charged an additional $8.32/animal for Revalor-XH, for a total of $21.57/animal. Heifers in the IH + 200 treatment were charged an additional $3.08/animal for Revalor-IH, $3.75/animal for Revalor-200, and a $1.50 chute charge for re-implant processing, for a total of $21.59/animal.

No major animal health differences occurred in the Horton et al. (2022) feeding trials, but observed morbidity and mortality were accounted for in the partial budget. Morbidity was not differentiated by diagnosis, and a $23.60/treatment charge (USDA-NAHMS, 2013) was assumed for any treatments administered. An estimated render fee of $40.50/animal mortality was used. This value was determined with an assumed inflation adjustment based on a $24.11 cost for rendering a beef animal as reported by Sparks Companies Inc. (2002); the value is anecdotally similar to what feedlots indicate they pay currently. The inflation adjustment was performed by adjusting the 2002 Producer Price Index (PPI) for animal slaughtering and processing (U.S. BLS) to the mean PPI from 2017 through 2022.

The only variable cost component was FYP. These were monthly price data from the CattleFax ration price database for the Central Plains region. The prices account for dry feed, feed markup, and yardage. Feedlots use various custom feeding charge structures as some markup feed and charge yardage; others only markup feed with no yardage; and some only charge yardage with no feed markup. Therefore, a single FYP is used rather than incorporating feed, markup, or yardage as individual components. Price points for FYP (Table 1) were multiplied by the total amount of dry feed delivered per pen throughout the period to estimate total feed and yardage cost, with each price point representing a separate partial budget with all other variable components fixed at the Middle value.

To account for money borrowing for the purchase of feeder heifers and feed, a fixed yearly interest rate of 5.85% [based on the mean rate for operation loans in Kansas from 2017 through 2022 (Ag Credit Survey, Federal Reserve Bank of KS City)] was incorporated with the purchase cost of heifers, and one-half of the total cost of feed and yardage. Interest cost was applied as the interest rate [5.85% × (pen DOF/365)] multiplied by the total heifer purchase cost of the pen, and 1/2 of the total pen feed and yardage cost. Rushton (2007) describes "discounting" as the process of converting future dollar values into current dollar values, as there is a basic principle that a current dollar (or other unit of currency) is worth more than any future dollar yet to be received, because the current dollar can accumulate more than its original value by being invested; here, discounting is synonymous with accounting for opportunity cost. In order to approximate the opportunity cost of waiting additional days to market cattle when revenue could instead be received earlier, interest was used for estimation. The same 5.85% rate was applied only to + 21 and + 42 pens, which was the interest rate [5.85% × (21 or 42/365)] multiplied by the revenue received for the corresponding BASE treatment pen within each block.

Revenue components were either from live or dressed (adjusted for carcass-based premiums and discounts) fed heifer prices (Table 1), in addition to revenue from culled animals. For the live sale scenario, variable fed cattle prices were determined from weekly negotiated heifer prices (live free-on-board, over 80% Choice) from the USDA-AMS 5 Area Weekly Weighted Average Direct Slaughter Cattle report with 4% pencil shrink. For the dressed sale scenario, variable fed cattle base prices were determined using a fixed dressed yield applied to live prices. The base pen revenue was then adjusted for QG, YG, and weight premiums or discounts using the pen-level HCW in each category. Specific prices for QG were described in the prior section and are listed in Table 1. Premiums and discounts for YG and weight (LM_CT169; USDA-AMS) had little variability from 2017 through 2022 and have minimal influence on revenue variability (Schroeder and Graff, 2000; Tatum et al., 2006), therefore, those components were held constant. Price determination was similar to that of variable components in the sensitivity analyses, where the minimum and maximum values from the date range were determined, and the Middle value was used for YG and weight premiums and discounts. Specific prices are reported in Table 2.

Revenue from culled cattle removed from the trial for health reasons was estimated by using a proportion of reported cull cow prices, determined by removed animal weight, per Horton et al. (2021). Prices from the National Weekly Direct Cow and Bull Report—Negotiated Price for dressed Breaker cows over 227 kg (500 lb) were used (LM_CT168; USDA-AMS). Weekly prices from 2017 through 2022 were selected, and a fixed Middle price of $125.00/cwt was chosen using methodology similar to the selection of variable components. Mean pen-level HCW of removed trial cattle was estimated using the following formula: HCW = 0.2598 × live $BW^{1.1378}$ (Tatum et al., 2012), where live BW was the actual live weight of the animal at the time of trial removal. A percentage of the Breaker cow price was used, as determined by mean estimated HCW categorization, where HCW less than 181 kg (400 lb) received 59.5% of the price, HCW between 181 and 271 kg (400 to 599 lb) received 76.3% of the price, and HCW greater than 272 kg (600 lb) received 92.0% of the price (Horton et al., 2021). Estimated total pen-level HCW from culls was multiplied by the appropriate adjusted price to estimate culled cattle revenue. Values of fixed components used in partial budgets for sensitivity analyses are in Table 2.

Statistical analyses

Linear mixed models were fit to evaluate treatment effects on net return and net grid revenue adjustments using commercially available software (Proc GLIMMIX, SAS 9.4; SAS Institute Inc., Cary, NC). The models were specified with a Gaussian distribution and identity link function using restricted maximum likelihood estimation and a Kenward-Rodger degrees of freedom adjustment. Fixed effects were implant program, DOF, and implant program × DOF; random intercepts for trial, and block within trial were used to account for clustering by the experimental design. Pen served as the experimental unit in all analyses. Conditional and marginal plots of studentized residuals were assessed visually to evaluate model assumptions of normality and homogeneous residual variance. Statistical significance was declared *a priori* at $\alpha = 0.05$. Main effects are reported in the absence of significant two-way interactions, and a Tukey-Kramer adjustment for multiple comparisons was used for evaluating pairwise comparisons of treatment differences. For interpretation, model-adjusted mean differences (as opposed to means) and standard errors of the differences (SED) compared to a referent treatment are reported.

Results and Discussion

There were no significant two-way interactions in any statistical model (*P*-values ≥ 0.14), therefore, only main effects of implant programs and DOF are shown. The mean purchase cost per heifer did not significantly differ between implant programs (*P* = 0.64) or differing DOF (*P* = 0.18), even though additional interest cost on the purchase of feeder heifers was applied to pens fed for longer days (data not shown). There was no significant difference in initial BW between treatments (Horton et al., 2022), which provides rationale for finding similar purchase costs. While feeder cattle price is highly influential on cattle feeding profit (Mark et al., 2000), it was not incorporated as a variable component in sensitivity analyses because it was a "sunk" cost that would have minimal impact treatment differences.

Heifers in the XH treatment had consistently lower net returns of more than $10/animal compared to IH + 200 when sold on a live basis (FYP fixed at $320.00/907 kg DM), regardless of live-fed cattle price (*P*-values ≤ 0.03) (Table 3). The estimated difference between implant programs increased by $0.55/animal with each $15.00/cwt increase in live-fed price. These results were expected being that there were negligible processing cost differences across implant programs and no evidence of differences in cattle health (Horton et al., 2022), thus, the main factors influencing live net return are feed costs and sales revenue. Heifers administered IH + 200 were more feed efficient than XH (Horton et al., 2022), meaning reduced feed costs per unit of weight gain. Feed efficiency on its own can often be a misleading metric as it may be improved by (1) increased ADG, (2) decreased dry matter intake (DMI), or (3) the combination of both. As is often the case in animal science literature, significant treatment effects on gain:feed may occur while significant differences in weight and intake are not observed (as was the case for Horton et al. 2022), even though they are the two drivers. Therefore, it is important to not discard numerical differences of components that trigger feed efficiency changes because when combined, the numerical differences may result in significant differences in net returns. While not statistically significant, IH + 200 had 2 kg heavier final BW and numerically greater ADG (Horton et al., 2022), which would result in more revenue compared to XH. Additionally, there was an implant program × DOF interaction for DMI, where XH heifers had greater DMI than IH + 200 when fed for longer DOF (Horton et al., 2022), which would contribute to increased feed and yardage costs.

On a dressed sale basis (FYP fixed at $320.00/907 kg DM; CS-spread fixed at $15.00/cwt), net returns were again lower

Table 3. Model-adjusted mean differences and standard errors of the differences (SED) for estimated net returns of beef feedlot heifers administered one of two implant programs and fed for three differing days-on-feed (DOF) from sensitivity analyses with varying live and dressed-fed cattle base prices while holding all other budget components constant*

Fed cattle base price	Implant program†		SED	*P*-value	Days-on-feed‡			SED	*P*-value	*P*-value
	IH + 200	XH			BASE	+ 21	+ 42			Implant × DOF
Live price, net return ($/animal)§										
$95.00/cwt	ref	−10.12	4.401	0.03	ref[a]	−36.40[b]	−75.96[c]	5.391	<0.01	0.18
$110.00/cwt	ref	−10.67	4.441	0.02	ref[a]	−29.64[b]	−63.62[c]	5.438	<0.01	0.22
$125.00/cwt	ref	−11.22	4.512	0.02	ref[a]	−22.89[b]	−51.29[c]	5.526	<0.01	0.27
$140.00/cwt	ref	−11.77	4.614	0.02	ref[a]	−16.14[b]	−38.96[c]	5.651	<0.01	0.33
$155.00/cwt	ref	−12.32	4.744	0.02	ref[a]	−9.38[a]	−26.63[b]	5.811	<0.01	0.40
Dressed base price, net return ($/carcass)‖										
$149.00/cwt	ref	−15.28	6.428	0.02	ref[a]	−22.81[b]	−57.39[c]	7.873	<0.01	0.33
$172.00/cwt	ref	−16.60	6.435	0.02	ref[a]	−15.37[a]	−42.43[b]	7.881	<0.01	0.38
$196.00/cwt	ref	−17.98	6.466	<0.01	ref[a]	−7.60[a]	−26.83[b]	7.919	<0.01	0.44
$219.00/cwt	ref	−19.29	6.519	<0.01	ref	−0.16	−11.87	7.984	0.24	0.50
$243.00/cwt	ref	−20.67	6.598	<0.01	ref	7.61	3.73	8.080	0.64	0.57

*Data are from pooled analyses from three trials described by Horton et al. (2022), using a 2 × 3 factorial treatment arrangement in a randomized complete block design with 10,583 crossbred beef heifers that were blocked by arrival within trial and allocated to pens (144 total) which were randomized to treatment (within block), resulting in 24, 72, and 48 replications of simple effects, implant program effects, and DOF effects, respectively.
†Implant programs: XH = cattle implanted only at trial enrollment with Revalor-XH (Merck Animal Health, Lenexa, KS), a dual-component extended release implant with a total of 200 mg trenbolone acetate (TBA) and 20 mg estradiol (E_2); or IH + 200 = cattle implanted at trial enrollment with Revalor-IH (Merck Animal Health; 80 mg TBA and 8 mg E_2) and re-implanted with Revalor-200 (Merck Animal Health; 200 mg TBA and 20 mg E_2) after approximately 90 DOF.
‡Days-on-feed: cattle were fed to a feedlot standard baseline (BASE) endpoint, or an additional + 21 or + 42 DOF beyond BASE (within block).
§Differences in net return means [(total pen revenue—total pen cost)/animal shipped] compared to a referent (ref) category with varying live-fed cattle prices; the feed and yardage price was fixed at 320.00 $/907 kg (2,000 lb) dry matter; cwt = 45.4 kg (100 lb).
‖Differences in net return means [(total pen revenue—total pen cost)/carcass] compared to a referent (ref) category with varying dressed-fed cattle base prices; the feed and yardage price was fixed at 320.00 $/907 kg (2,000 lb) dry matter; carcass premiums and discounts ($/cwt) for USDA Quality Grade were fixed at 15.00, 0.00, −15.00, and −29.00 for Prime, Choice, Select, and sub-Select grades, respectively; cwt = 45.4 kg (100 lb).
a,b,cUncommon superscripts within row for DOF indicate significant difference ($P \leq 0.05$) after adjustment for multiple comparisons.

for XH compared to IH + 200, regardless of the dressed-fed cattle base price (*P*-values ≤ 0.02; Table 3). With each increase in dressed base price (Low through High), the net return difference between implant programs increased by over $1.30/carcass. In addition to having a feed efficiency advantage (discussed previously), on a carcass basis IH + 200 heifers had 2 kg heavier HCW, and a greater dressed yield than XH (Horton et al., 2022). Net return differences between implant programs were numerically greater on a dressed sale basis than live, by $5.16 (Low price) to $8.35 (High price) per animal (Table 3). While selling cattle on a grid has been noted to increase cattle price variability, cattle with higher dressing percentages typically return more revenue when sold on a dressed basis when compared to live (Schroeder and Graff, 2000); this may explain why the magnitude of differences between implant programs was greater when sold on a carcass basis than when sold live.

On a live-sale basis (Table 3; FYP fixed at $320.00/907 kg DM), extending DOF reduced net returns with fed cattle prices of 95.00, 110.00, 125.00, or 140.00 $/cwt (*P*-values < 0.01), where net returns for heifers fed + 21 DOF were lower than BASE but greater than + 42 heifers, which had the overall poorest net returns. Using the High live-fed cattle price ($155.00/cwt), feeding for + 42 DOF reduced net returns compared to BASE and + 21 ($P < 0.01$), while there was no evidence of a difference comparing + 21 with BASE at this price. Compared to BASE, estimated decreases in net return for + 21 and + 42 were greatest when live-fed cattle prices were low, and were less severe at higher prices, holding FYP constant. Relative differences compared to BASE decreased by approximately 6.75 and 12.33 $/cwt for each incremental increase in the live-fed cattle price for + 21 and + 42, respectively. Additional revenue from having heavier final BW for longer-fed heifers did not outweigh costs associated with additional feed and yardage, opportunity cost, and having reduced feed efficiency through poorer ADG (Horton et al., 2022). While reductions in net return for + 21 and + 42 heifers compared to BASE became smaller with higher live-fed cattle prices, none of the selected fed cattle prices would incentivize longer feeding horizons.

On a dressed sale basis (FYP fixed at $320.00/907 kg DM; CS-spread fixed at $15.00/cwt), there was a DOF effect on net returns when the dressed-fed cattle base price was 149.00, 172.00, and 196.00 $/cwt (*P*-values < 0.01; Table 3). For these prices, net returns were poorest for + 42 heifers compared to BASE and + 21. At the Low price ($149.00/cwt) + 21 net returns were also significantly lower than BASE; conversely, there was no evidence of a difference in returns between BASE and + 21 at Mid-Low ($172.00/cwt) and Middle ($196.00/cwt) dressed-fed cattle base prices. There was no evidence of a difference between DOF treatments when dressed-fed cattle base prices were 219.00 ($P = 0.24$) or 243.00 $/cwt ($P = 0.64$). With each incremental increase in the dressed base price (Low through High), estimated net return differences per animal were reduced by over 7.44 and 14.96 $/cwt for + 21 and + 42, respectively, compared to BASE. The estimated net return differences compared to BASE were larger in magnitude at each respective price on a live sale basis than on a dressed sale basis; meaning that when feeding for longer DOF, one may expect larger changes in net return to occur when marketing live as opposed to dressed. When extending DOF, the importance of live feed efficiency and daily gain is of lesser consequence when marketing dressed (vs live). While these metrics have been shown to decrease with additional DOF (Horton et al., 2022), the proportion of weight being deposited in carcass components increases while growth of non-carcass components (e.g., hide, internal organs, head) become more stagnant (Berg and Butterfield, 1968; Buckley et al., 1990; Coleman et al., 1995; Owens et al., 1995; Wilken et al., 2015; Honig et al., 2022), thereby providing a mechanism for the distinction between live and dressed-sale basis net returns. Horton et al. 2022 described this concept as incremental dressing percentage, which is a contrast between live growth and carcass growth, or, the proportion of live BW gain that results in carcass weight gain. On average, the estimated incremental dressing percentage was 76.2% for heifers fed + 42 d beyond BASE. As heifers fed for addional DOF were depositing more salable weight in the carcass as opposed to "drop" (non-carcass) components, dressing percent concurrently increased. Because the dressed-fed base prices were a fixed percentage of the corresponding live-fed prices, heifers with higher dressed yields and marketed dressed have an advantage when opposed to live marketing. In other words, heifers fed additional DOF beyond BASE capitalize by having a greater proportion of weight sold on a dressed basis compared to the live price equivalent (more weight multiplied by the same reference price). Nevertheless, there was minimal evidence to support extending DOF when evaluating variable dressed-fed cattle prices; the only occurrence of positive net return estimates for both + 21 and + 42 compared to BASE, while not significant, was with a High dressed-fed cattle base price.

The opportunity cost of feeding cattle for longer DOF had a substantial impact on model estimates. Descriptively, mean opportunity costs (± 1 SD) for + 21 heifers sold live were 4.13 (0.416), 4.78 (0.480), 5.43 (0.544), 6.08 (0.609), and 6.73 (0.673) \$/animal for Low, Mid-Low, Middle, Mid-High, and High fed cattle price points, respectively. For + 42 heifers sold live, mean opportunity costs (± 1 SD) were 8.27 (0.831), 9.57 (0.960), 10.87 (1.089), 12.17 (1.217), and 13.47 (1.346) \$/animal for Low, Mid-Low, Middle, Mid-High, and High fed cattle price points, respectively. On a dressed sale basis, mean opportunity costs were nearly identical to live sale opportunity costs at each price point for + 21 (within -0.02 and -0.05 \$/carcass difference) and + 42 DOF (within -0.04 and -0.10 \$/carcass difference). When considering feeding pens of cattle longer, producers are likely to consider factors such as additional feed and yardage cost, interest on feed and cattle purchase, and the potential increased risk of late-day morbidity and mortality [(Engler et al., 2014; Vogel et al., 2015; Smith et al., 2022) although evidence of effects on these health outcomes was not observed in the data used herein (Horton et al., 2022)]. As an additional consideration, the opportunity cost of keeping cattle on feed longer represents a sizeable "penalty" on net returns of heifers fed for extended DOF.

As a secondary objective, net grid revenue adjustments from carcass-based premiums and discounts were evaluated at varying CS-spread prices (Table 4). This is the estimated difference in \$/carcass revenue adjustments that are applied to base carcass value (heifers grading Choice, YG 3). Compared to IH + 200, heifers administered XH received more revenue from grid adjustments, regardless of the CS-spread (P-values < 0.01), and as CS-spreads increased (from Low to High), estimated grid revenue differences became larger. Net return per carcass when varying the CS-spread is also in Table 4 (FYP fixed at \$320.00/907 kg DM; dressed-fed cattle price fixed at \$196.00/cwt). Heifers in the XH program had poorer net returns per carcass than IH + 200 at all CS-spread price points (P-values ≤ 0.03); the estimated difference was greatest at the Low CS-Spread (\$-19.57/carcass), decreased incrementally at each higher CS-spread, and was lowest at the High CS-spread (\$-15.57/carcass). The observed decrease in net return differences with increasing CS-spreads relates to the decreases in net grid revenue for IH + 200, as XH heifers received more grid revenue from having carcasses with higher QG.

When evaluating effects of DOF on premiums and discounts (Table 4), heifers fed for + 21 or + 42 DOF received more revenue from grid adjustments compared to BASE, regardless of the CS-spread (P-values < 0.01), and grid revenue differences became larger as CS-spreads widened. There was no evidence of a difference in net grid revenue between + 21 and + 42 DOF treatments at any selected CS-spread. Results suggest that under the CS-spreads selected, treatment groups with higher QG received more revenue from grid adjustments, even with a corresponding increase in YG 4 and 5 carcasses (Horton et al., 2022). There also was not a discernably negative impact of heavyweight carcasses (> 476 kg) which occurred for + 42 heifers compared to + 21 and BASE (Horton et al., 2022), likely because the magnitude of the increase was small at less than 1 out of 100 carcasses. While these estimated grid revenue adjustments may be useful for conceptualizing the impacts that shifts in QG and YG have when using a value-based pricing structure, base revenue from Choice and YG 3 carcasses, and costs associated with extending DOF are not accounted for. The circumstances change once accounting for the additional factors that contribute to overall net returns. Days-on-feed affected net returns (Table 4) at all CS-spreads (FYP fixed at \$320.00/907 kg DM; dressed-fed cattle price fixed at \$196.00/cwt). At Low, Mid-Low, and Middle CS-spreads (5.00, 10.00, and 15.00 \$/cwt, respectively; P-values < 0.01), heifers fed + 42 DOF had lower net returns compared to BASE and + 21. Note that results from the Middle CS-spread are identical to those for the Middle dressed-fed cattle base price (\$196.00/cwt) in Table 3, as both are reflective of having all variable components set at the Middle price point. Days-on-feed also affected net returns at Mid-High (\$20.00/cwt; P < 0.01) and High (\$25.00/cwt; P = 0.03) CS-spreads, where + 42 heifers had poorer net returns than BASE, while there was not a significant difference comparing + 21 heifers with BASE or + 42. While additional DOF beyond BASE resulted in greater net grid revenue adjustments at every CS-spread, there was no evidence of an advantage for longer DOF in net returns as a whole once accounting for additional variables such as FYP and opportunity cost.

Previous research has reported that HCW is the most important determinant for revenue when using grid-based pricing, while grid premiums and discounts and carcass performance comprise a smaller proportion of revenue variability (McDonald and Schroeder, 2003; Johnson and Ward, 2005; Tatum et al., 2006, 2012). The magnitude of grid importance increases with wider CS-spreads, with higher premiums paid to higher QG (Johnson and Ward, 2005; Tatum et al., 2006). Our results concur with these prior studies. Varying dressed-fed cattle base prices resulted in larger estimated treatment differences with each increase in price compared to incremental increases of the CS-spread. This indicates that in terms

Table 4. Model-adjusted mean differences and standard errors of the differences (SED) for net grid revenue adjustments and overall net returns of beef feedlot heifers administered one of two implant programs and fed for three differing days-on-feed (DOF) from sensitivity analyses varying the Choice-Select spread for USDA Quality Grade premiums and discounts while holding all other budget components constant*

Choice-Select spread	Implant program[†]				Days-on-feed[‡]					*P*-value
	IH + 200	XH	SED	*P*-value	BASE	+ 21	+ 42	SED	*P*-value	Implant × DOF
Spread, net grid revenue[§] ($/carcass)										
$5.00/cwt[‖]	ref	3.20	1.198	<0.01	ref[a]	3.55[b]	4.51[b]	1.467	<0.01	0.71
$10.00/cwt[¶]	ref	3.92	1.446	<0.01	ref[a]	4.23[b]	5.75[b]	1.770	<0.01	0.72
$15.00/cwt[**]	ref	4.80	1.766	<0.01	ref[a]	5.17[b]	7.44[b]	2.163	<0.01	0.69
$20.00/cwt[††]	ref	5.84	2.136	<0.01	ref[a]	6.38[b]	9.58[b]	2.616	<0.01	0.66
$25.00/cwt[‡‡]	ref	7.21	2.573	<0.01	ref[a]	8.11[b]	12.62[b]	3.151	<0.01	0.65
Spread, net return[§§] ($/carcass)										
$5.00/cwt[‖]	ref	−19.57	6.367	<0.01	ref[a]	−9.27[a]	−29.84[b]	7.798	<0.01	0.51
$10.00/cwt[¶]	ref	−18.85	6.401	<0.01	ref[a]	−8.56[a]	−28.56[b]	7.834	<0.01	0.47
$15.00/cwt[**]	ref	−17.98	6.466	<0.01	ref[a]	−7.60[a]	−26.83[b]	7.919	<0.01	0.44
$20.00/cwt[††]	ref	−16.94	6.563	0.02	ref[a]	−6.38[ab]	−24.65[b]	8.038	<0.01	0.41
$25.00/cwt[‡‡]	ref	−15.57	6.708	0.03	ref[a]	−4.63[ab]	−21.59[b]	8.215	0.03	0.39

*Data are from pooled analyses from 3 trials described by Horton et al. (2022), using a 2 × 3 factorial treatment arrangement in a randomized complete block design with 10,583 crossbred beef heifers that were blocked by arrival within trial and allocated to pens (144 total) which were randomized to treatment (within block), resulting in 24, 72, and 48 replications of simple effects, implant program effects, and DOF effects, respectively.
[†]Implant programs: XH = cattle implanted only at trial enrollment with Revalor-XH (Merck Animal Health, Lenexa, KS), a dual-component extended release implant with a total of 200 mg trenbolone acetate (TBA) and 20 mg estradiol (E_2); or IH + 200 = cattle implanted at trial enrolment with Revalor-IH (Merck Animal Health; 80 mg TBA and 8 mg E_2) and re-implanted with Revalor-200 (Merck Animal Health; 200 mg TBA and 20 mg E_2) after approximately 90 DOF.
[‡]Days-on-feed: cattle were fed to a feedlot standard baseline (BASE) endpoint, or an additional + 21 or + 42 DOF beyond BASE (within block).
[§]Mean differences in grid revenue from premiums and discounts compared to a referent (ref) category with varying Choice-Select spreads (i.e., the pen-level sum of Quality, Yield, and weight-based premium and discount revenue divided by *n* carcasses per pen).
[‖]Carcass premiums and discounts ($/cwt) for USDA Quality Grade: Prime = 14.00, Choice = 0.00, Select = -5.00, sub-Select = -21.00; cwt = 45.4 kg (100 lb).
[¶]Carcass premiums and discounts ($/cwt) for USDA Quality Grade: Prime = 14.00, Choice = 0.00, Select = −10.00, sub-Select = −25.00; cwt = 45.4 kg (100 lb).
[**]Carcass premiums and discounts ($/cwt) for USDA Quality Grade: Prime = 15.00, Choice = 0.00, Select = −15.00, sub-Select = −29.00; cwt = 45.4 kg (100 lb).
[††]Carcass premiums and discounts ($/cwt) for USDA Quality Grade: Prime = 17.00, Choice = 0.00, Select = −20.00, sub-Select = −33.00; cwt = 45.4 kg (100 lb).
[‡‡]Carcass premiums and discounts ($/cwt) for USDA Quality Grade: Prime = 21.00, Choice = 0.00, Select = −25.00, sub-Select = −37.00; cwt = 45.4 kg (100 lb).
[§§]Differences in net return means [(total pen revenue—total pen cost)/carcass] compared to a referent (ref) category with varying Choice-Select spreads (with Prime and sub-Select premiums and discounts adjusted accordingly); the dressed-fed cattle base price was fixed at 196.00 $/cwt; feed and yardage price was fixed at 320.00 $/907 kg (2,000 lb) dry matter.
[a,b]Uncommon superscripts within row for DOF indicate significant difference ($P \leq 0.05$) after adjustment for multiple comparisons.

of feeding heifers longer, the dressed-fed cattle base price is likely a more influential deciding factor than the CS-spread. Programs such as Certified Angus Beef, which award premiums for carcasses grading in the upper 2/3 Choice (while requiring other conditions met), were not incorporated in these analyses. Such programs could provide additional revenue opportunities when using grid-based pricing.

Sensitivity analyses of FYP are in Table 5. Note the $320.00/907 kg DM FYP analyses are identical to Middle price points in Table 3, as they are representative of setting all variable components at the Middle price point. On a live sale basis (live-fed cattle price fixed at $125.00/cwt), XH heifers had lower net returns than IH + 200 regardless of the FYP (*P*-values ≤ 0.04); the difference between implant programs increased by approximately $0.96/animal for every $45.00/907 kg increase in FYP. Similarly, on a dressed sale basis (dressed-fed cattle base price fixed at $196.00/cwt; CS-spread fixed at $15.00/cwt), XH heifers had lower net returns than IH + 200 regardless of the FYP (*P*-values < 0.01); and the difference between implant programs increased by approximately $0.84/animal for every $45.00/907 kg increase in FYP. In essence, the value-added by the IH + 200 implant program compared to XH increased with increasing FYP. The previous discussion on the effects of implant programs on feed efficiency are of high relevance here as well. The capability to convert similar or reduced feed resources to heavier live or carcass weight is of particular importance when varying FYP, providing probable reasoning for the observed increasing advantage of IH + 200 heifers when increasing FYP compared to XH.

On a live sale basis, there was no evidence of a difference between differing DOF when using the Low ($230.00/907 kg DM) FYP (Table 5; *P* = 0.14). Days-on-feed affected net returns at all other FYP when sold live (*P*-values < 0.01). Heifers fed + 42 DOF had lower net returns compared to BASE and + 21 at the Mid-Low ($275.00/907 kg DM) FYP. At all other FYP (Middle, Mid-High, and High), + 21 heifers had lower net returns than BASE, and + 42 had lower returns than both + 21 and BASE. With each $45.00 increase in FYP, the net return difference between + 21 and BASE widened by over $10.50/animal, and the difference between + 42 and BASE widened by over $20.75/animal. On a dressed sale basis, the only case of positive estimated net return differences for + 21 and + 42 compared to BASE was at the Low FYP, however, these differences were not significant (Table 5; *P* = 0.11). There also was not evidence of a DOF effect using the Mid-Low FYP (*P* = 0.48). Net returns decreased with additional DOF at Middle ($320.00/907 kg DM), Mid-High ($365.00/907 kg DM), and High ($410.00/907 kg DM) price points (*P*-values < 0.01). At the Middle and Mid-High FYP, + 42 heifers had lower net returns compared to BASE and + 21. At the High FYP, + 21 heifers had lower net returns

Table 5. Model-adjusted mean differences and standard errors of the differences (SED) for estimated net returns of beef feedlot heifers administered one of two implant programs and fed for three differing days-on-feed (DOF) from sensitivity analyses with varying feed and yardage prices on a live or dressed cattle sale basis while holding all other budget components constant*

Feed and yardage price	Implant program†		SED	*P*-value	Days-on-feed‡			SED	*P*-value	*P*-value
	IH + 200	XH	SED	*P*-value	BASE	+ 21	+ 42	SED	*P*-value	Implant × DOF
Live sales net return, $/animal§										
$230.00/907 kg DM	ref	−9.30	4.270	0.04	ref	−1.76	−9.73	5.230	0.14	0.49
$275.00/907 kg DM	ref	−10.26	4.381	0.03	ref[a]	−12.32[a]	−30.51[b]	5.366	<0.01	0.37
$320.00/907 kg DM	ref	−11.22	4.512	0.02	ref[a]	−22.89[b]	−51.29[c]	5.526	<0.01	0.27
$365.00/907 kg DM	ref	−12.18	4.661	0.02	ref[a]	−33.46[b]	−72.07[c]	5.709	<0.01	0.20
$410.00/907 kg DM	ref	−13.15	4.827	<0.01	ref[a]	−44.02[b]	−92.85[c]	5.912	<0.01	0.14
Dressed sales net return, $/carcass‖										
$230.00/907 kg DM	ref	−16.29	6.025	<0.01	ref	12.89	14.10	7.379	0.11	0.60
$275.00/907 kg DM	ref	−17.13	6.238	<0.01	ref	2.65	−6.37	7.640	0.48	0.51
$320.00/907 kg DM	ref	−17.98	6.466	<0.01	ref[a]	−7.60[a]	−26.83[b]	7.919	<0.01	0.44
$365.00/907 kg DM	ref	−18.82	6.708	<0.01	ref[a]	−17.85[a]	−47.29[b]	8.215	<0.01	0.37
$410.00/907 kg DM	ref	−19.66	6.961	<0.01	ref[a]	−28.09[b]	−67.75[c]	8.526	<0.01	0.32

*Data are from pooled analyses from 3 trials described by Horton et al. (2022), using a 2 × 3 factorial treatment arrangement in a randomized complete block design with 10,583 crossbred beef heifers that were blocked by arrival within trial and allocated to pens (144 total) which were randomized to treatment (within block), resulting in 24, 72, and 48 replications of simple effects, implant program effects, and DOF effects, respectively.
†Implant programs: XH = cattle implanted only at trial enrollment with Revalor-XH (Merck Animal Health, Lenexa, KS), a dual-component extended release implant with a total of 200 mg trenbolone acetate (TBA) and 20 mg estradiol (E_2); or IH + 200 = cattle implanted at trial enrollment with Revalor-IH (Merck Animal Health; 80 mg TBA and 8 mg E_2) and re-implanted with Revalor-200 (Merck Animal Health; 200 mg TBA and 20 mg E_2) after approximately 90 DOF.
‡Days-on-feed: cattle were fed to a feedlot standard baseline (BASE) endpoint, or an additional + 21 or + 42 DOF beyond BASE (within block).
§Differences in net return means [(total pen revenue—total pen cost)/animal shipped] compared to a referent (ref) category with varying feed and yardage prices; 907 kg = 1 US ton (2,000 lb); DM = dry matter; the live-fed cattle price was fixed at 125.00 $/cwt.
‖Differences in net return means [(total pen revenue—total pen cost)/carcass] compared to a referent (ref) category with varying feed and yardage prices; the dressed-fed cattle base price was fixed at 196.00 $/cwt; carcass premiums and discounts ($/cwt) for USDA Quality Grade were fixed at 15.00, 0.00, −15.00, and −29.00 for Prime, Choice, Select, and sub-Select grades, respectively.
[a,b,c]Uncommon superscripts within row for DOF indicate significant difference ($P \leq 0.05$) after adjustment for multiple comparisons.

than BASE, and + 42 had lower returns than both + 21 and BASE. With each $45.00 increase in FYP and selling dressed, the net return difference between + 21 and BASE became more negative by approximately $10.25/animal, and the difference between + 42 and BASE widened by nearly $20.50/animal.

Use of a common re-implanting program (IH + 200) had an economic advantage over a single extended-duration implant (XH), regardless of the variable pricing component. Estimated differences between the programs were greater when heifers were sold dressed (vs live), and increased with higher fed cattle prices as well as with higher FYP. The only case of a moderate decrease in estimated net return differences between implant programs was with increasing CS-spreads. Recently updated US Food and Drug Administration (FDA) guidance currently restricts the use of the IH + 200 implant program among others (FDA, 2021, 2023). Therefore, model estimates provided herein may be less meaningful to producers, but represent an important constraint of a management tool. Economic advantages of re-implanting cattle with combination implants containing estrogenic and anabolic androgenic steroid components compared to non-implanted controls, or cattle receiving a single implant have previously been reported [(Duckett et al., 1996; Duckett and Pratt, 2014) noting that Revalor-XH was not available at the time for inclusion]. Economic and environmental efficiencies improve for beef production systems that use growth enhancing technologies compared to those that do not (Wileman et al., 2009; Capper and Hayes, 2012). While the FDA guidance does not constitute complete removal of a technology, as some alternative implants labeled for use sequentially in the same production phase are available [e.g., Synovex Choice (10 mg estradiol benzoate, 100 mg TBA) followed by Synovex Plus (28 mg estradiol benzoate, 200 mg TBA), Zoetis Animal Health, Parsippany, NJ], industry stakeholders should expect a reduction in both economic and environmental sustainability by limiting certain cattle implanting programs that had previously been available.

When evaluating extending DOF in the feedlot, past publications have mentioned economic implications. However, this is the first peer-reviewed publication known by the authors to conduct economic analyses from clinical trial data which incorporate a serial harvest component as part of the experimental design. A recent systematic review indicated inconsistent reporting of methodologies behind calculation of economic outcomes from experimental trials evaluating feedlot cattle performance and health, often leading to the inability to reproduce, or properly interpret the validity of results (Dixon et al., 2022). These factors limit some formal comparisons with the literature. Wilken et al. (2015) evaluated a similar research question for steers using differing methodology. Regression equations were applied to pooled clinical trial data without a DOF treatment factor, to predict performance of steers had they been fed for 75%, 100%, or 125% of their normal DOF. They evaluated differing DOF with steers sold on a live or carcass basis not accounting for carcass-based premiums and discounts at 3 different feed prices (158.96, 249.79, and 340.63 $/907 kg DM). General findings from Wilken et al. (2015) were that net returns were similar when sold live or dressed at any feed price when marketing at 100% DOF. When marketing at 125% DOF, net returns were greatest when selling dressed at any feed price selected compared to live. When selling live, only at the $158.96/kg feed price was 125% DOF advantageous compared to 75% or 100% DOF. These results contrast those observed herein, where there was no significant evidence for increased returns when extending DOF. Dissimilarities between study results could be due to biological differences between heifers and steers, the prices evaluated, and experimental design (i.e., use of a DOF treatment factor vs cattle performance predictions from regression equations). Additionally, it is unclear if Wilken et al. (2015) accounted for opportunity cost when extending DOF in their analyses.

Overall, our results do not support extended feeding of feedlot heifers. Reduced net returns compared to BASE occurred in every analysis when selling on a live basis, except with Low FYP showing no significant difference. Similarly, when selling on a dressed basis, there was no evidence of greater net returns for extended DOF. Instances where there was no evidence of a DOF effect on net returns when selling dressed were with Mid-high and High fed cattle base prices, and Low to Mid-Low FYP. At the time of this publication, current FYP are nearest to the High price point (CattleFax), while fed cattle prices have exceeded the High price used herein (LM_CT150; USDA-AMS).

There are limitations of this publication to consider. For one, it is critical to keep the scope of inference in mind as it pertains to generalization of results. Time of trial conduct, region, and cattle demographics are all important considerations. For example, it is uncertain how similar analyses would apply to steers, which should likely be an area of future research. In addition to physiological distinctions between heifers and steers due to differences in growth and maturity (Owens et al., 1995), one should also consider that the selection of a BASE reference group is relative, and likely changes with time. Where a group of heifers stand physiologically on a growth curve will in all likelihood result in alternative implications when adding DOF. Heifers were never sorted by BW or other measurement factors into more homogeneous groups (pens) due to design of the trials; this practice is often used to reduce the number of YG 4, 5, and heavyweight carcasses that would receive discounts under grid-based pricing. This management strategy could be conducive with extending DOF, but could not be evaluated in this research. Estimates provided in results are reflective of pen-level management of feedlot heifers, but do not necessarily reflect what is always optimal for feedlot-level management decisions. For example, marketing cattle earlier allows pen-space for the next set of feeder cattle to be placed in the feedlot, which may be a viable option when feeder prices are low. Conversely, if feeder cattle prices are high and (or) they are of limited availability, producers may opt towards feeding current cattle longer to maintain fuller feedlot occupancy. Finally, while the sensitivity analysis approach is valuable for depicting the relative importance, magnitude, and direction of changes that occur when varying individual pricing components, the reality is more dynamic, where the components are often associated with each other and fluctuate concurrently. One could envision pricing conditions where it may be favorable to extend feedlot heifer DOF; e.g., it is probable that cattle fed longer will receive a different sale price then those marketed earlier, which could be advantageous (or disadvantageous) as marketing windows could be shifted based on yearly market trends (Mark et al., 2002; Peel and Meyer, 2002). In other words, there may be seasonal effects on whether one would extend or shorten the finishing period of feedlot heifers, depending on anticipated prices. However, such pursuit was outside the objective of the analyses performed.

Conclusions and Implications

Fed cattle prices, CS-spread, and FYP all had important implications on the net returns of feedlot heifers administered differing implant programs and fed for varying DOF. The re-implant program (IH + 200) consistently had greater net returns compared to the single delayed-release implant program (XH), regardless of the pricing component. Differences can be expected to be larger between implant programs when marketing heifers on a dressed basis compared to live. However, as of the time of this publication, the IH + 200 program cannot be used in the US per current FDA regulations. While current trends have been to feed cattle to heavier endpoints, there was no evidence to support longer feeding of heifers beyond BASE from an economic standpoint in the pooled trials. If one opts to feed heifers beyond their standard endpoint, it would be advisable to market them on a dressed basis (assuming a constant relationship between live and dressed prices, and no major changes to premiums and discounts for YG and weight), be under high fed cattle pricing conditions, and to consider additional costs incurred, particularly for feed, yardage, interest, and opportunity cost.

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Conflict of Interest Statement

Merck Animal Health employs JH and MS; their contributions were intellectual as they did not partake in data collection or analyses. No competitive interest was present due to non-use or evaluation of competing products. There are no conflicts of interest to disclose.

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