The effects of implant strategy on finished body weight of beef cattle

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ABSTRACT: We summarized experimental data to quantify the change in final BW due to a particular implant strategy when cattle are adjusted to the same final body composition. The database developed for this study included 13 implant trials involving a total of 13,640 animals (9,052 steers and 4,588 heifers). Fifteen different implant strategies were used among these trials, including no implant (control), single implants, and combinations of implants. Individual carcass data collected at slaughter were used to calculate the adjusted final shrunk BW at 28% empty body fat (AFBW) for each treatment group within a trial, then the implant treatments were grouped into categories according to their effect on weight at 28% empty body fat (four groups for steers and two groups for heifers). All differences in AFBW between categories were significant ($P < 0.01$), indicating an incremental anabolic implant dose response in AFBW over unimplanted animals. Values for AFBW ranged from 520 kg in unimplanted steers to 564 kg in steers implanted and reimplanted with Revalor-S. For heifers, AFBW ranged from 493 kg in unimplanted heifers to 535 kg in heifers implanted and reimplanted with Revalor-H. After accounting for differences in mean BW and composition of gain, implanted steers and heifers had 4.2 and 3.1% higher apparent diet ME values, respectively. Increasing the anabolic implant dose increases the weight at which animals reach a common body composition. This study indicates that anabolic implant response is due to a combination of a reduced proportion of the DMI required for maintenance, reduced energy content of gain, and efficiency of use of absorbed energy.

Key Words: Animal Models, Cattle, Growth, Growth Promoters, Management

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Introduction

Individual animal management systems have been developed to maximize individual animal profitability while ensuring consistency in meat quality, which requires all animals to be harvested at the target body composition. However, these objectives can be difficult to achieve due to differences in mature size. Small-framed animals reach optimum body composition at light BW, which limits both the amount of edible meat per animal and profitability. Large-framed animals reach optimum body composition at heavy weights, sometimes exceeding carcass weight limits (Fox and Perry, 1996).

There are two possible options for modifying the inherited mature size of cattle (NRC, 2000): 1) placing animals on different planes of nutrition and 2) using a particular anabolic implant strategy. Anabolic implants are known to shift the composition of gain in cattle by increasing protein deposition and decreasing fat at a particular weight (NRC, 1984, 2000). Implanted animals reach the same body composition at a heavier weight compared to unimplanted animals (Hutcheson et al., 1997; Perry et al., 1991).

The objective of this study was to quantify the change in final BW due to a particular implant strategy when animals are adjusted to the same final body composition. This information can be used to identify the implant strategy most appropriate for each individual animal in order to maximize profitability and consistency in meat quality. A second objective was to determine whether implants improve apparent diet ME values after accounting for differences in composition of gain.

Materials and Methods

Treatment Description and Animal Database. The database summarized included 13 implant trials involving a total of 13,640 animals (9,052 steers and 4,588 heifers). Fifteen different implant strategies were used among these trials, including no implant (control), single implants, and combinations of implants. Table 1 describes the 10 different types of implant used in these trials, including their composition and doses. Table 2

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Table 1. Composition, doses, and acronyms describing implants utilized in the trials evaluated in this study

Implant[a]	Acronym	Composition and doses, in mg				
		Estradiol	Trenbolone acetate	Progesterone	Testosterone	Zeranol
No implant	No	—	—	—	—	—
Revalor-G	Rev-G	8[c]	40	—	—	—
Revalor-3[b]	Rev-3	12[c]	60	—	—	—
Revalor-IS	Rev-IS	16[c]	80	—	—	—
Revalor-S	Rev-S	24[c]	120	—	—	—
Revalor-IH	Rev-IH	8[c]	80	—	—	—
Revalor-H	Rev-H	14[c]	140	—	—	—
Synovex-S	Syn-S	20[d]	—	200	—	—
Synovex-H	Syn-H	20[d]	—	—	200	—
Component ES	Comp-ES	20[d]	—	200	—	—
Ralgro	Ral	—	—	—	—	36

[a]All Revalor products are manufactured by Intervet, Inc., Millsboro, DE 19966. Synovex implants are manufactured by Ft. Dodge Animal Health, Fort Dodge, IA 50501. Component implants are manufactured by Ivy Labs, Overland Park, KS 66214, and Ralgro is manufactured by Schering-Plough Animal Health Corp., Union, NJ 07083.
[b]Non-commercial experimental implant.
[c]Estradiol 17β.
[d]Estradiol benzoate.

summarizes the trials included in this study, indicating number of animals, sex, implant treatments, reimplanting day, total days on feed, and average initial BW (**iBW**) for each trial. There were five trials (1, 2, 6, 10, and 11) without a control treatment. Reimplanting day ranged from 64 to 90 d from the beginning of the trial. Only two treatments had a reimplanting time out of this range (35 d) but were part of the experimental design of that trial and therefore were considered distinct treatments. Average iBW ranged from 246 to 296 kg in heifers and from 263 to 339 kg in steers except in trial 10, in which it was 431 kg. Animals in this trial were implanted only once and therefore the iBW resembled those from the other studies at reimplanting time.

Description of Animals and Diets of Each Trial. Two thousand fifty-nine English crossbred heifers were used in trial 1. There were five implant treatments and four pens per treatment. The trial was conducted in Parma, ID from August 1999 to December 1999 for a total of 133 d. The final ration on a DM basis contained 43% high-moisture ear corn, 26% rolled corn, 17.5% wheat, 3.5% fat, 3.5% alfalfa hay, 3.5% supplement, and 3% canola meal. Melengesterol acetate (**MGA**; Pharmacia Animal Health, Kalamazoo, MI) was included in the final ration. One thousand nine hundred forty-six medium- and large-framed English × Continental and English × English heifers were used in trial 2. There were five implant treatments and four pens per treatment. The trial was conducted in Cactus, TX from May 1999 to September 1999 for a total of 141 d. The final ration on a DM basis contained 53% steam-flaked corn, 22.4% high-moisture corn, 7% alfalfa hay, 4.2% corn silage, 3.6% animal fat, 2% molasses, and 7.7% of a supplement. Melengesterol acetate was included in the final ration. Two hundred sixty-eight medium-framed 1/2 Charlois × English × 1/5 Brahman heifers were used in trial 3. There were six implant treatments and eight pens per treatment. The trial was conducted in Lubbock, TX from August 1999 to April 2000 for a total of 230 d. The final ration on a DM basis contained 65% steam-flaked corn, 10% whole shelled corn, 5% cottonseed hulls, 5% ground alfalfa hay, 4.4% cottonseed meal, 4% molasses, 3% yellow grease, and 4% supplement. Melengesterol acetate was not included in the ration. Three hundred fourteen English × Continental crossbred heifers were used in trial 4. There were six implant treatments and eight pens per treatment. The trial was conducted in Urbana, IL from November 1998 to May 1999 for a total of 189 d. The final ration on a DM basis contained 62% high-moisture corn, 15% corn gluten pellets, 15% corn silage, and 13% supplement. Melengesterol acetate was not included in the ration. Four hundred forty-one Angus and Angus × Continental crossbred steers were used in trial 5. There were six implant treatments and eight pens per treatment. The trial was conducted in Wellington, CO from December 1998 to June 1999 for a total of 207 d. The final ration on a DM basis included 71.6% steam-flaked corn, 18.7% corn silage, 7.5% supplement, and 2.2% soybean meal. One thousand, nine hundred thirty-four English × Continental steers were used in trial 6. There were five implant treatments and four pens per treatment. The trial was conducted in Parma, ID from June 1999 to November 1999 for a total of 157 d. The final ration on a DM basis contained 43% ground high-moisture ear corn, 27% wheat, 17% rolled corn, 3.5% fat, 3.5% supplement, 3.5% alfalfa hay, and 2.5% canola meal. Three hundred eighty medium- to large-framed English and English × Continental steers were used in trial 7. There were six implant treatments and eight pens per treatment. The trial was conducted in Parma, ID from No-

Table 2. Summary of trials evaluated in this study[a]

Trial	n	Location	DOF	Pen/Trt	Re-implant	iBW, kg	Treatments (initial/second implant)[b]
Heifers							
1	2,059	Parma, ID	133	4	65 d	293	Rev-H, Syn-H/Rev-H, Rev-IH/Rev-H, Rev-IH/Rev-IH, and Rev-H/Rev-H
2	1,946	Cactus, TX	141	4	69 d	296	Rev-H, Syn-H/Rev-H, Rev-IH/Rev-H, Rev-IH/Rev-IH, and Rev-H/Rev-H
3	268	Lubbock, TX	230	8	84 d	246	Control, No/Rev-H, Rev-H, Rev-H/Rev-H, Rev-IH/Rev-H, and Syn-H/Rev-H
4	314	Urbana, IL	189	8	84 d	269	Control, No/Rev-H, Rev-H, Rev-H/Rev-H, Rev-IH/Rev-H, and Syn-H/Rev-H
Steers							
5	441	Wellington, CO	207	8	83 d	263	Control, No/Rev-S, Rev-G/Rev-S, Rev-3/Rev-S, Rev-IS/Rev-S, and Syn-S/Rev-S
6	1,934	Parma, ID	157	4	71 d	339	Rev-S, Syn-S/Rev-S, Rev-IS/Rev-S, Rev-IS/Rev-IS, and Rev-S/Rev-S
7	380	Parma, ID	210	8	90 d	280	Control, Rev-S/Rev-S, No/Rev-S, Rev-G/Rev-S, Syn-S/Rev-S, and Ral/Rev-S
8	2,284	Cactus, TX	154	4	64 d	316	Control, Rev-S, No/Rev-S, Rev-G/Rev-S, Syn-S/Rev-S, and Ral/Rev-S
9	469	Mead, NE	194	8	84 d	271	Control, No/Rev-S, Rev-G/Rev-S, Rev-3/Rev-S, Rev-IS/Rev-S, and Syn-S/Rev-S
10	800	Syracuse, KS	118	4	—	431	Rev-S, Rev-IS, and Comp-ES
11	1,938	Cactus, TX	153	4	71 d	335	Rev-S, Syn-S/Rev-S, Rev-IS/Rev-S, Rev-IS/Rev-IS, and Rev-S/Rev-S
12	476	Brooking, SD	144	8	35 d/70 d	319	Control, No/Rev-S 35d, No/Rev-S, Rev-G/Rev-S 35d, Rev-G/Rev-S, and Rev-S
13	331	Concord, NE	166	7	66 d	324	Control, Rev-S, No/Rev-S, Rev-G/Rev-S, Syn-S/Rev-S, and Ral/Rev-S

[a]Thirteen studies with a total of 13,640 animals; DOF = days on feed, Trt = treatment, iBW = initial BW.
[b]Acronyms of implants are described in Table 1.

vember 1997 to June 1998 for a total of 210 d. The final ration on a DM basis contained 42.5% ground, ensiled high-moisture ear corn, 37% wheat, 14.5% pressed beet pulp, 1.5% alfalfa hay, and 4.5% supplement. Two thousand, two hundred eighty -our English and English × Continental steers were used in trial 8. There were six implant treatments and four pens per treatment. The trial was conducted in Cactus, TX from August 1997 to January 1998 for a total of 154 d. The final diet on a DM basis contained 51.7% steam-flaked corn, 23.3% high-moisture corn, 8.5% alfalfa hay, 3.7% corn silage, 2% molasses, 3.1% alfalfa hay, and 7.7% supplement. Four hundred sixty-nine English and English × Continental steers were used in trial 9. There were six implant treatments with 10 steers per pen. The trial was conducted in Mead, NE from November 1998 to June 1999 for a total of 194 d. The final diet on a DM basis contained 82% dry-rolled corn, 7.5% alfalfa hay, 3.5% molasses, and 7% supplement. Eight hundred steers from a Simbrah × Brangus × Bradford composite dam crossed on an Angus sire were used in trial 10. There were three implant treatments and four pens per treatment. The trial was conducted in Syracuse, KS from May 2000 to September 2000 for a total 118 d. The final ration on a DM basis contained 46.8% steam-flaked corn, 34.6% high-moisture corn, 6.7% alfalfa hay, 1.9% molasses, 4% animal fat, and 6.2% supplement. A total of one thousand, nine hundred thirty-eight medium- and large-framed English × Continental and English × English steers were used in trial 11. There were five implant treatments and four pens per treatment. The trial was conducted in Cactus, TX from June 1999 to November 1999 for a total of 153 d. The final ration on a DM basis contained 66.7% steam-flaked corn, 9.7% high-moisture corn, 7.7% alfalfa hay, 2.5% corn silage, 3.6% animal fat, 1.9% molasses, and 7.9% supplement. Four hundred seventy-six English × Continental steers were used in trial 12. There were a total of six implant treatments and eight pens per treatment. The trial was conducted in Brookings, SD from January 1998 to June 1998 for a total of 144 d on feed. The final ration on a DM basis contained 56% whole shelled corn, 28% high-moisture corn, 8% grass hay, 3.5% soybean meal, and 4.3% supplement. Three hundred thirty-one English × Continental steers were used in trial 13. There were a total of six implant treatments and seven pens per treatment. The trial was conducted in Concord, NE from September 1997 to March 1998 for a total of 166 d. The final ration on a DM basis contained 54% dry-rolled corn, 27% high-moisture corn, 5% alfalfa hay, 5% corn silage, 6% supplement, and 3% soybean meal.

*Computing Adjusted Final Shrunk BW (***AFBW***).* Empty BW is computed from hot carcass weight using the relationship developed by Garrett et al. (1978; Eq. [1]). To compute the change in final BW (**fBW**) at the same body composition as affected by a particular implant or implant strategy, it is necessary to adjust each animal's actual fBW to that BW expected at the target body composition. This adjustment was performed using the procedure developed by Guiroy et al. (2001), who found that empty body fat (**EBF**) could be computed from carcass measurements typically available at harvest, including 12th rib fat thickness, hot carcass weight, USDA quality grade, and longissimus muscle area (**LMA**; Eq. [2]). Then, the actual BW at harvest can be adjusted to the BW expected at 28% EBF, because an average change in empty BW of 14.26 kg was required to change body fat one percentage unit (Eq. [3]):

$$EBW = (1.316 \times HCW) + 32.29 \quad [1]$$

$$EBF = 17.76207 + (4.68142 \times FT) + (0.01945 \times HCW) + (0.81855 \times QG) - (0.06754 \times LMA) \quad [2]$$

$$AFBW = (EBW + [(28 - EBF) \times 14.26])/0.891 \quad [3]$$

where EBW is empty BW (kg), EBF is empty body fat (% EBW), FT is fat thickness (cm), HCW is hot carcass weight (kg), QG is quality grade (Standard = 3 to 4; Select = 4 to 5; low Choice = 5 to 6; mid-Choice = 6 to 7; high Choice = 7 to 8; low Prime = 8 to 9; mid-Prime = 9 to 10), LMA is longissimus muscle area (cm^2), and AFBW is shrunk BW adjusted to 28% EBF.

Evaluating Feed Efficiency. Anabolic implants alter metabolism so that a greater proportion of absorbed nutrients is used for protein synthesis and deposition (NRC, 1994). Therefore, to evaluate differences in performance between implanted and unimplanted cattle, the allocation of ME to NE_m and(or) NE_g must be determined, or the diet ME can be modified until predicted and observed performance agree after maintenance and growth requirements are determined based on mean and final BW and composition. We chose the latter approach because information available is not adequate to determine how to adjust allocation of ME to NE_m and NE_g with the use of an anabolic implant. The dietary concentration of ME required for the observed growth was computed for each pen within a trial (apparent ME). This was accomplished by iterating ME values in the feed required calculation described by Guiroy et al. (2001) until actual feed consumed by the pen matched the predicted feed required. In this procedure, NE_m required for the pen mean BW and NE_g required for the pen mean ADG and mean shrunk BW (**SBW**) equivalent to the standard reference weight (**EQSBW**) are computed, based on the AFBW computed by Eq. [1] to [3]. Then, feed for maintenance is computed by dividing the NE_m required by the diet NE_m and feed for gain is computed by dividing the NE_g required by the diet NE_g. Diet NE_m and NE_g values are computed from diet ME, using the NRC (2000) equations. The pen observed DM intake is assigned a beginning ME appropriate for a high-energy ration, which is then changed until the predicted DM required matches actual DM consumed. The resulting apparent ME values for each implant treatment were then tested for significant differences.

Statistical Analysis. All the analyses in this study were performed using SAS (SAS Inst. Inc., Cary, NC). Steers and heifers were analyzed separately. The analysis of animal performance was done within trial and sex using PROC MIXED. In this analysis, the pen was used as the experimental unit and weighted by number of animals in each pen. In computing changes in AFBW by implant or implant strategy, a mixed linear model was chosen to account for fixed effects (treatments) and random effects (trials). The experimental unit was each animal. Least squares means (LSMeans) for AFBW of the mixed model were computed for each treatment and all pairwise differences among treatments were evaluated. Treatments that were not significantly different ($P > 0.10$) in AFBW were grouped in common categories. Then, a new mixed model was developed to determine differences in AFBW among the above categories. Differences in apparent ME values due to implant or implant strategy were analyzed on a pen basis within trial due to differences in energy concentration of diets among studies. A linear model was chosen (PROC GLM) with treatments (implants) as fixed effects. When the overall F-value was significantly different ($P < 0.10$), apparent ME treatment means were compared using least squares means. A categorical data analysis (Agresti, 1996) was used to investigate the association of number of animals that received various implant strategies and two categories of USDA grades. The two categories were created combining animals in the USDA Standard and Select grades and animals in the USDA low Choice, Choice, high Choice, low Prime, and Prime grades. The χ^2 and Mantel-Haenszel tests were used in the contingency table analysis (Stokes et al., 2000).

Results and Discussion

Table 3 presents the ADG and Table 4 presents the gain:feed ratio of steers and heifers for each trial evaluated in this study. In general, animals in the control treatments had a lower ADG than animals in the implant strategies ($P < 0.05$). A similar pattern was also observed in the gain:feed ratio analysis (Table 4); however, in this case the implant strategies of trial 5 did not affect the animal performance compared to animals of control treatment. Table 5 presents the AFBW computed for each implant strategy with the 9,052 steers. Shrunk BW adjusted to 28% EBF ranged from 520 kg in unimplanted steers to 564 kg in steers implanted and reimplanted with Revalor-S. Table 5 also shows implant strategies with similar AFBW (not different within a category at $P > 0.10$) grouped in five categories, including the mean AFBW for each category and the change increment from the no implant treatment. All differences in AFBW between categories were significant ($P < 0.01$). This analysis and information on composition and dose of each implant from Table 1 indicates an incremental anabolic implant dose response in AFBW over unimplanted steers. The increment was the

Table 3. Effects of different implant strategies on average daily gain (kg/d) in steers and heifers

		Treatment[d]														
Trial	Implant: Reimplant	None None	Rev-H/S None	Rev-IS None	Comp-ES None	None Rev-H/S	Rev-G Rev-S (35)	None Rev-S (35)	Ral Rev-S	Syn-H/S Rev-H/S	Rev-IH/IS Rev-IH/IS	Rev-G Rev-S	Rev-3 Rev-S	Rev-IH/IS Rev-H/S	Rev-H/S Rev-H/S	SE
1		—	1.86	—	—	—	—	—	—	1.84	1.86	—	—	1.89	1.89	0.03
2		—	1.42	—	—	—	—	—	—	1.38	1.38	—	—	1.37	1.40	0.03
3		0.99^{a}	1.13^{b}	—	—	1.14^{b}	—	—	—	1.17^{b}	—	—	—	1.36^{b}	1.15^{b}	0.04
4		1.15^{a}	1.28^{b}	—	—	1.28^{b}	—	—	—	1.31^{b}	—	—	—	1.34^{b}	1.31^{b}	0.04
5		1.44^{a}	—	—	—	1.59^{b}	—	—	—	1.61^{bc}	—	1.65^{bc}	1.68^{c}	1.67^{bc}	—	0.04
6		—	1.91	—	—	—	—	—	—	1.93	1.96	—	—	1.94	1.95	0.02
7		1.22^{a}	—	—	—	1.37^{b}	—	—	1.43^{bc}	1.44^{c}	—	1.46^{c}	—	—	1.49^{c}	0.03
8		1.18^{a}	1.35^{b}	—	—	1.35^{b}	—	—	1.42^{bc}	1.43^{c}	—	1.43^{c}	—	—	—	0.03
9		1.39^{a}	—	—	—	1.56^{b}	—	—	—	1.61^{bc}	—	1.60^{bc}	1.60^{bc}	1.63^{c}	—	0.04
10		—	1.58	1.54	1.47	—	—	—	—	—	—	—	—	—	—	0.08
11		—	1.48	—	—	—	—	—	—	1.48	1.50	—	—	1.46	1.47	0.03
12		1.44^{a}	1.65^{c}	—	—	1.62^{b}	1.64^{b}	1.69^{bc}	—	—	—	1.70^{c}	—	—	—	0.03
13		1.32^{a}	1.49^{b}	—	—	1.46^{b}	—	—	1.52^{b}	1.57^{b}	—	1.58^{b}	—	—	—	0.06

[a,b,c]Within a row, means without a common superscript letter differ ($P < 0.05$). SE is the average SE of the least squares means pairwise comparison.
[d]Acronyms of implants are described in Table 1. H/S or IH/IS mean heifer (trials 1 to 4) or steer (trials 5 to 13) formulations, respectively.

Table 4. Effects of different implant strategies on gain to feed ratio (g/kg) in steers and heifers

		Treatment[d]														
Trial	Initial: Reimplant:	None None	Rev-H/S None	Rev-IS None	Comp-ES None	None Rev-H/S	Rev-G Rev-S (35)	None Rev-S (35)	Ral Rev-S	Syn-H/S Rev-H/S	Rev-IH/IS Rev-IH/IS	Rev-G Rev-S	Rev-3 Rev-S	Rev-IH/IS Rev-H/S	Rev-H/S Rev-H/S	SE
1		—	208	—	—	—	—	—	—	207	210	—	—	215	211	2.58
2		—	173	—	—	—	—	—	—	171	173	—	—	172	175	1.38
3		168^{a}	176^{b}	—	—	183^{b}	—	—	—	183^{b}	—	—	—	181^{b}	183^{b}	3.75
4		153^{a}	166^{b}	—	—	170^{b}	—	—	—	169^{b}	—	—	—	169^{b}	169^{b}	2.68
5		204	—	—	—	227	—	—	—	222	—	226	220	227	—	5.65
6		—	200	—	—	—	—	—	—	202	205	—	—	204	205	2.17
7		150^{a}	—	—	—	164^{b}	—	—	163^{b}	162^{b}	—	165^{b}	—	—	164^{b}	2.36
8		138^{a}	150^{b}	—	—	155^{bc}	—	—	159^{c}	158^{c}	—	158^{c}	—	—	—	2.67
9		155^{a}	—	—	—	168^{b}	—	—	—	172^{b}	—	169^{b}	170^{b}	171^{b}	—	3.40
10		—	162	162	156	—	—	—	—	—	—	—	—	—	—	7.20
11		—	168	—	—	—	—	—	—	170	173	—	—	170	170	2.23
12		151^{a}	164^{b}	—	—	167^{bc}	171^{c}	168^{bc}	—	—	—	172^{c}	—	—	—	3.43
13		131^{a}	142^{b}	—	—	144^{b}	—	—	147^{b}	148^{b}	—	152^{b}	—	—	—	5.18

[a,b,c]Within a row, means without a common superscript letter differ ($P < 0.05$). SE is the average SE of the least squares means pairwise comparison.
[d]Acronyms of implants are described in Table 1. H/S or IH/IS mean heifer (trials 1 to 4) or steer (trials 5 to 13) formulations, respectively.

Table 5. Shrunk body weight adjusted to 28% empty body fat (AFBW) for 14 different implant strategies on steers

Implants[a]	n[b]	AFBW[c], kg	Category	Common AFBW, kg	Change in AFBW, kg
Control	730	519.5	1	519.5[d]	—
Comp-ES	267	529.9	2	533.1[e]	13.7 ± 4.6
Rev-IS	266	536.5			
No/Rev-S	732	549.4			
Rev-S	1,567	549.8			
Rev-G/Rev-S 35d	78	544.5	3	549.8[f]	30.4 ± 2.3
No/Rev-S 35d	80	548.4			
Ral/Rev-S	493	551.5			
Syn-S/Rev-S	1,414	554.3			
Rev-IS/Rev-IS	794	555.2	4	554.7[g]	35.3 ± 2.3
Rev-G/Rev-S	730	555.2			
Rev-3/Rev-S	154	562.6			
Rev-IS/Rev-S	915	558.7	5	561.1[h]	41.8 ± 2.6
Rev-S/Rev-S	832	563.7			

[a]Initial implant/second implant. Acronyms for implants are described in Table 1.
[b]Number of pooled animals per treatment.
[c]The AFBW values within a category are not statistically different ($P > 0.10$). Average SE of the least squares mean pairwise comparison was 4.88 kg.
[d,e,f,g,h]Within a column, means without a common superscript letter differ ($P < 0.01$). Average SE of the least squares mean pairwise comparison was 2.99 kg.

lowest (13.7 ± 4.6 kg) in category 2, which included animals receiving either an estrogenic implant (**Comp-ES**) or an intermediate dose of estradiol-17β plus trenbolone acetate (**TBA**) (**Rev-IS**). This increment was the highest (41.8 ± 2.6 kg) in category 5, which included animals receiving Revalor-S, Revalor-IS, or Rev-3 as the first implant and Revalor-S as the second implant. The other categories (3 and 4) fell in between 2 and 5, reflecting the dose response previously mentioned. The SE for the prediction of the increase in AFBW was low, especially for categories 3, 4, and 5 in Table 5.

Table 6 presents the results for heifers using the same analysis described above for steers. The AFBW values ranged from 493 kg in unimplanted heifers to 532 kg in heifers implanted and reimplanted with Revalor-H. The analysis of the heifer trials resulted in three different categories of implant strategies. Results from Table 6 indicate increments in AFBW over no implant similar to those shown for steers in Table 5.

Table 7 shows the number of steers or heifers in each of the USDA quality grades and the percentage grading USDA Choice, or higher, for each of the five implant categories for steers and the three implant categories for heifers. Unimplanted steers averaged 62.5% low Choice or greater; values for implanted steers were lower. Unimplanted heifers averaged 52.5% low Choice or greater; the value for those in implant category 2 were higher whereas that of implant category 3 was lower. The categorical data analysis indicated an association between implant categories and USDA grades (*P*

Table 6. Shrunk body weight adjusted to 28% empty body fat (AFBW) for seven different implant strategies on heifers

Implants[a]	n[b]	AFBW[c], kg	Category	Common AFBW, kg	Change in AFBW, kg
Control	52	493.5	1	493.5[d]	—
Rev-H	809	521.8			
Rev-IH/Rev-IH	805	525.1	2	523.6[e]	30.2 ± 5.8
No/Rev-H	99	525.5			
Rev-IH/Rev-H	888	531.6			
Syn-H/Rev-H	896	531.6	3	532.2[f]	38.8 ± 5.7
Rev-H/Rev-H	894	534.5			

[a]Initial implant/second implant. Acronyms for implants are described in Table 1.
[b]Number of pooled animals per treatment.
[c]The AFBW values within a category are not statistically different ($P > 0.10$). Average SE of the least squares mean pairwise comparison was 4.97 kg.
[d,e,f]Within a column, means without a common superscript letter differ ($P < 0.01$). Average SE of the least squares mean pairwise comparison was 3.83 kg.

< 0.01) for steers and heifers. However, because these were all time-constant trials and Table 6 shows implanted cattle should reach the same EBF (as % of empty BW) at a heavier weight, these data have limited value in determining the effect of implants on carcass grade. Perry et al. (1991) studied the growth performance and composition of gain responses to an implant containing both TBA and estradiol in three breed types of steers when harvested at the same degree of marbling as determined by ultrasound. Within each of the breed categories (Holsteins, Angus, and Angus × Simmental), final marbling scores and carcass fat percentages were not different between implanted and unimplanted steers. Table 7 also shows the average predicted EBF for the cattle in each USDA quality grade within each of the implant categories, demonstrating the variability in EBF at a particular grade. In some comparisons, implanted cattle had significantly more EBF than controls at the same grade. In other cases, the EBF was similar in adjacent quality grades; this reflects differences in marbling in cattle at the same EBF. The EBF at a particular quality grade were similar to those reported by Guiroy et al. (2001) for controls but were typically higher for implanted cattle. This is likely due to differences in breed types in this data base (no Holsteins and some Brahman breeding).

Results in the evaluation of differences between implant strategies in apparent ME values are presented in Table 8 for steers. Trials (6, 10, and 11) that did not include a control (no implant) treatment resulted in no significant differences in apparent ME values as affected by implant strategy. The other six studies that included a control treatment (5, 7, 8, 9, 12, and 13) indicated that apparent ME values were significantly ($P < 0.10$) greater for implanted steers. This increase averaged 4.2% across these studies (4.5, 2.3, 4.4, 3.8, 5.7, and 4.4% increase in apparent ME for the above trials, respectively). Similar analysis was performed for heifers and is presented in Table 9. In trial 4, which included a control, apparent ME use in heifers was improved 3.1% in implanted heifers. Trial 3 had a control treatment but the apparent ME was not different between implant strategies ($P = 0.15$). However, this trial had the longest days on feed and days from reimplant to slaughter (230 and 146 d, respectively) among all trials evaluated, which could have reduced the implant effect.

Many studies have shown the growth response to anabolic steroids, but few have included measurement of carcass or body composition changes, which is necessary to understand their mode of action (NRC, 1994). Total lean carcass mass increased 9.5 and 10.4% in steers implanted twice with 300 mg TBA and 36 mg resorcylic acid lactone over the live weight range of 250 to 400 kg (Griffiths, 1982). Implanting steers with Revalor-S increased carcass protein approximately 10% over unimplanted steers (Johnson et al., 1996). Keane and Drennan (1987) found that implanted cattle had 23.1 kg more lean, with the increase in carcass weight accounted for entirely by the increase in carcass lean.

Table 7. Average USDA quality grade and predicted empty body fat within a USDA quality grade for each implant category

Sex	Category	Ch–[a] %	Variable[b]	USDA grade[c] Std	Se	Ch–	Ch	Ch+	Pr–	Pr
Steers	1	62.5	n	11	261	297	93	35	18	11
			EBF	26.0	27.7	29.3[y]	30.5[y]	31.3[y]	31.5[y]	33.0
Steers	2	56.8	n	4	226	153	130	17	3	—
			EBF	26.0	28.1	30.2[x]	31.5[xy]	33.7[x]	39.0[x]	—
Steers	3	55.3	n	74	1,242	1,139	339	95	35	20
			EBF	25.1	28.0	29.7[x]	31.0[y]	32.3[xy]	32.4[y]	33.2
Steers	4	54.2	n	83	1,261	1,152	298	114	16	9
			EBF	25.4	28.1	29.9[x]	31.1[y]	32.3[x]	32.8[y]	32.9
Steers	5	46.3	n	99	921	657	163	58	3	—
			EBF	24.8	27.9	29.7[xy]	31.6[x]	31.5[y]	32.0[y]	—
Steers			SE	0.94	0.20	0.23	0.35	0.68	1.09	0.91
Heifers	1	52.5	n	—	47	35	12	4	1	—
			EBF	—	25.6	27.6[xy]	27.9[y]	30.9	30.3	—
Heifers	2	56.0	n	49	746	746	182	57	22	6
			EBF	23.3	25.9	28.0[x]	29.5[x]	31.1	32.0	32.8
Heifers	3	49.8	n	77	1,266	1,005	239	62	21	6
			EBF	23.2	27.7	27.6[y]	29.5[x]	30.8	32.3	30.7
Heifers			SE	0.41	0.28	0.34	0.55	0.97	1.50	2.12

[a]Percentage of animals that graded USDA low Choice (Ch–) or greater. There is an association between implant strategies and USDA grades ($P < 0.01$).

[b]n is number of animals, EBF is empty body fat, % of empty BW, and SE is the average SE of the least squares means pairwise comparison.

[c]USDA grades are Std = Standard, Se = Select, Ch– = low Choice, Ch = Choice, Ch+ = high Choice, Pr– = low Prime, and Pr = Prime.

[x,y]Within a column and same sex, means without a common superscript letter differ ($P < 0.01$).

Table 8. Effects of implant strategy on apparent dietary ME after accounting for differences in composition of gain of steers[a]

Trial	n	Control[b]	Trt[c] *P*-value	Implants[c]	Apparent ME, Mcal/kg	SE
5	48	Yes	0.059	Control	3.49[w]	0.05
				No/Rev-S	3.72[x]	0.05
				Rev-3/Rev-S	3.56[wx]	0.05
				Rev-G/Rev-S	3.67[x]	0.05
				Rev-IS/Rev-S	3.67[x]	0.05
				Syn-S/RevS	3.62[w]	0.05
6	20	No	0.116	Overall mean	3.43	—
7	48	Yes	0.006	Control	2.87[w]	0.02
				No/Rev-S	2.96[x]	0.02
				Ral/Rev-S	2.94[x]	0.02
				Rev-G/Rev-S	2.94[x]	0.02
				Rev-S/Rev-S	2.92[x]	0.02
				Syn-S/Rev-S	2.92[x]	0.02
8	24	Yes	<0.001	Control	2.77[w]	0.02
				No/Rev-S	2.89[x]	0.02
				Ral/Rev-S	2.92[x]	0.02
				Rev-S	2.83[x]	0.02
				Rev-G/Rev-S	2.91[x]	0.02
				Syn-S/Rev-S	2.91[x]	0.02
9	48	Yes	0.016	Control	2.84[w]	0.03
				No/Rev-S	2.92[x]	0.03
				Rev-3/Rev-S	2.95[x]	0.03
				Rev-G/Rev-S	2.95[x]	0.03
				Rev-IS/Rev-S	2.95[x]	0.03
				Syn-S/Rev-S	2.97[x]	0.03
10	12	No	0.431	Overall mean	3.19	—
11	20	No	0.237	Overall mean	3.07	—
12	48	Yes	<0.001	Control	2.92[w]	0.02
				No/Rev-S	3.08[xy]	0.02
				No/Rev 35d	3.08[xy]	0.02
				Rev-S	3.03[x]	0.02
				Rev-G/Rev-S	3.11[y]	0.02
				Rev-G/Rev-S 35d	3.13[y]	0.02
13	42	Yes	0.023	Control	2.72[w]	0.03
				No/Rev-S	2.84[xy]	0.03
				Ral/Rev-S	2.83[xy]	0.03
				Rev-S	2.80[x]	0.03
				Rev-G/Rev-S	2.89[y]	0.03
				Syn-S/Rev-S	2.84[xy]	0.03

[a]Nine trials with a total of 310 pens (n).
[b]Control row indicates whether a control treatment was present or not in that trial.
[c]Acronyms of implants are described in Table 1. Control means no implants, and Trt means treatment effect.
[w,x,y]Within a column and trial, means without a common superscript letter differ ($P < 0.01$).

Few studies have examined the effects of anabolic steroids in cattle fed to the same chemical compositional end point, which is necessary to determine the effect on finished weight and feed efficiency. Across all groups in the Perry et al. (1991) experiment described previously, implants increased ADG by 22%, daily protein gain by 29%, and daily fat gain by 19%, resulting in live weight required to reach the same marbling end point being significantly ($P < 0.01$) increased. Feed efficiency was improved an average of 11.1%. The implant response in the Angus steers from the Perry et al. (1991) experiment was evaluated with the CNCPS model version 4.0 (Fox et al., 2000) to account for the independent effects of increased DMI, mean and final SBW and ADG, and apparent diet ME. Diets for implanted cattle had a 4.4% higher apparent ME than controls, compared to a 4.2% average for the six steer trials discussed in this study. This increase in apparent ME accounted for an 8.2% reduction in DM required per kilogram of ADG out of the total of 12.5% lower DM required/kg of ADG in these six trials.

This study confirms that anabolic implants increase mature body size of steers as reported by Preston (1978), Loy et al. (1988), and Owens et al. (1995) and increase BW at a common grade or body composition (Preston et al., 1990). In agreement with our results, Preston et al. (1990) concluded that implanted steers should be harvested at 39.5 kg heavier BW and im-

Table 9. Effects of implant strategy on apparent dietary ME after accounting for differences in composition of gain of heifers[a]

Trial	n	Control[b]	Trt[c] *P*-value	Implants[c]	Apparent ME, Mcal/kg[c]	SE
1	20	No	0.143	Overall mean	3.39	—
2	20	No	0.054	Rev	3.02[x]	0.01
				Rev-I/Rev	3.00[wx]	0.01
				Rev-I/Rev-I	3.03[x]	0.01
				Rev/Rev	3.02[x]	0.01
				Syn-H/Rev	2.98[w]	0.01
3	48	Yes	0.151	Overall mean	3.21	—
4	48	Yes	0.014	No	2.90[w]	0.02
				No/Rev	3.02[x]	0.02
				Rev	2.98[x]	0.02
				Rev-I/Rev	2.98[x]	0.02
				Rev/Rev	2.98[x]	0.02
				Syn-H/Rev	2.99[x]	0.02

[a]Four trials with a total of 136 pens (n).
[b]Control row indicates whether a control treatment was present or not in that trial.
[c]Acronyms of implants are described in Table 1. Control means no implants, and Trt means treatment effect.
[w,x,y]Within a column and trial, means without a common superscript letter differ ($P < 0.01$).

planted heifers at 16.8 kg heavier BW to achieve the same marbling score as controls.

This and other studies indicate the anabolic implant response is due to a combination of a decreased proportion of the DMI required for maintenance, reduced energy content of gain, and efficiency of use of absorbed energy. The NRC (2000) indicated the effect of an anabolic implant on energy requirement could be accounted for by increasing weight at the target harvest body composition by 25 to 45 kg if TBA plus estrogen is given, and by reducing this weight by that amount if no implant is given. The overall effect is to reduce energy content of gain by 5%. Our analysis indicated that the effect on diet energy values can be accounted for by increasing diet ME up to 4.2% in steers and up to 3.1% in heifers when given an anabolic implant.

Implications

This study provides evidence that increasing the anabolic implant dose increases the weight at which animals reach a common body composition. The data summary indicates finished BW is increased from 14 to 42 kg in steers and 30 to 39 kg in heifers, depending on the implant strategy used, in order to reach the same body composition at harvest as unimplanted animals. In addition, this study suggests that implants improve efficiency of use of absorbed energy after accounting for differences in composition of gain; however, there did not appear to be an implant dose response for diet ME utilization.

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