EFFECTS OF IMPLANTS AND MONENSIN ON BODY WEIGHT MAINTENANCE, FEEDLOT PERFORMANCE, AND CARCASS CHARACTERISTICS

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NOMENCLATURE

ADG	average daily gain
AOAC	Association of Official Analytical Chemists
CNEm	calculated net energy required for maintenance
cm	centimeters
d	days
DE	digestible energy
DES	diethylstilbestrol
DMI	dry matter intake
E17β	estradiol 17β
EBG	empty body gain
g	grams
hr	hours
kcal	kilocalorie
kg	kilograms
LMA	*longissimus* area
mcal	megacalorie
ME	metabolizabile energy
mg	milligrams
mm	millimeters

NEg	net energy required for gain
NEm	net energy required for maintenance
NEp	net energy for production
NRC	National Research Council
ppm	parts per million
RE	retained energy
RNEm	realized net energy required for maintenance
RNEg	realized net energy required for growth
TBA	trenbolone acetate
TDN	total digestible nutrients
TNEm	tabular net energy required for maintenance
^{o}C	degrees Celsius
U.S.	United States
USDA	United States Department of Agriculture
WBS	Warner-Bratzler shear force
YG	USDA yield grade

CHAPTER I

INTRODUCTION

In the United States, most calves are "grown" or "backgrounded" for a period of time before they enter the feedlot. Some of these calves are "dry wintered" on dormant native or improved warm season grasses. Because dormant grasses are of low quality, calves gain at very slow rates. Typically, energy intake is so low that cattle barely maintain their live weight. Although it has not been substantiated directly by research, many producers and researchers believe that estrogenic implants are not beneficial for cattle gaining less than .31 to .45 kg/d (Kuhl, 1997). If calves are implanted, should they be given an estrogen implant, an androgen implant (testosterone or trenbolone), or a combination of these two? Despite extensive discussion at a 1997 OSU sponsored symposium in Tulsa entitled "Impact of Growth Stimulants on Performance and Carcass Composition of Feedlot Cattle" with speakers from all parts of the U.S., the answers to these questions remain uncertain. Limited research conducted in Australia suggests that trenbolone acetate (TBA; 300 mg) implants may decrease energy requirements for maintenance (Hunter and Magner, 1990a); in contrast, research from the U.S. has suggested estrogenic implants will increase maintenance energy requirements (Rumsey et al., 1980).

Implants are used extensively in the U.S. for feedlot cattle to increase rate and efficiency of gain. However, research involving implants has shown that these growth enhancers may have adverse effects on carcass value -- suppressed marbling scores, advanced maturity, and less tender meat; thus, both producers and packers have begun to question the realized economic impact of implants. Effects of anabolic implants on feedlot performance and carcass attributes were reviewed by Duckett et al. (1997). Averaged across all implant types, anabolic agents administered during the finishing period increased daily gain by 18%; this represented a combined effect of 6% greater DM consumption and 8% less feed required per unit of live weight gain. Carcasses from implanted steers were heavier than their non-implanted counterparts; as a result, their carcasses had larger ribeye (*longissimus*) areas. However, implanting at the start of the finishing period had negative effects on both carcass maturity indices and USDA quality grades. Both implant type (estrogen, androgen, estrogen plus androgen) and frequency, through altering hormonal status, might be expected to alter live performance and carcass characteristics. Even though administration of anabolic agents during the finishing period has received the greatest scrutiny with regard to adverse effects on carcass traits, implanting cattle prior to the finishing phase also may negatively impact carcass quality and be responsible for the deterioration of beef quality outlined by Boleman et al. (1998). In support of this theory, Paisley et al. (1999) noted that anabolic implants administered more than nine months prior to feedlot placement adversely affected skeletal maturity, carcass quality, and thereby, carcass value.

Very few other studies have examined carryover effects of implant type and frequency during the growing phase on feedlot performance and carcass attributes. Positive (growth) benefits of anabolic implants must be weighed against the potential negative (carcass quality) effects to fully evaluate the economics of using implants and to assure that the beef industry provides the consumer with a desirable product.

Steers backgrounded on low quality forage often are fed a protein supplement but not an ionophore. Would inclusion of an ionophore benefit steers consuming low quality forage whose nutrient intake is at or near maintenance? Although direct research evaluating the effects of ionophores on maintenance energy requirements is lacking, the NRC (1996), extrapolating from feeding studies, proposed that monensin decreases the amount of energy required for maintenance by 12%; thereby, monensin should be quite useful for calves gaining little or no live weight. Effects of ionophores on feedlot performance have been evaluated or reviewed by Goodrich et al. (1984), Galyean and Owens, (1988), and Owens et al. (1991). Owens et al. (1991) also examined effects of ionophores on carcass attributes, while Owens and Gardner (1999) reviewed carcass, meat quality, and sensory responses. However, effects of including ionophores in the diet for backgrounding calves on subsequent feedlot performance have not been studied.

The studies that form this thesis were designed to estimate the effects of 1) various anabolic implants and 2) monensin supplementation on maintenance energy requirements by measuring weight retention responses of steers limit-fed

to maintain their body weight. In addition, carryover or residual effects of various anabolic implants and of monensin supplementation prior to finishing on subsequent feedlot performance and carcass attributes were quantified.

CHAPTER II

REVIEW OF LITERATURE

Energy Requirements

Overview of Energy Requirements. Lofgreen and Garrett (1968) were the first to introduce a system for cattle that separated energy available or required for maintenance (NEm) from that available or required for various types of production (NEp) that included body weight gain (NEg). This was noteworthy because ruminants utilize metabolizable energy with different efficiencies depending upon the animal's physiological state (maintenance, growth, lactation, and pregnancy). Today, the net energy system is used extensively to predict beef cattle energy requirements or predict growth rate from feed or net energy intake (NRC, 1984, 1996). Traditionally, maintenance energy requirements have been defined as the amount of dietary energy required to maintain constant body weight (NRC, 1976). However, because body composition (body energy content) can change even though concurrent weight does not change (Armstrong and Blaxter, 1984), the 1984 NRC defined the maintenance energy requirements more precisely as "the amount of feed energy required by an animal so that no

loss or gain in body composition occurs." By definition (Lofgreen and Garrett, 1967), net energy required for maintenance is considered to equal fasting heat production (heat produced by an animal not consuming feed) and is predicted by the equation NEm = 77 kcal/kg body weight$^{.75}$ (Lofgreen and Garrett, 1968). Because Lofgreen and Garrett (1968) determined fasting heat production for resting, inactive, non-stressed cattle, maintenance energy expenditures might well differ from this constant value due to differences in breed or genotype, gender, age, environmental conditions, physiological state, and previous plane of nutrition (NRC, 1984, 1996). For a more complete review of factors affecting maintenance energy requirements, readers are referred to reviews of Pullar and Webster (1977), Van Es (1980), Webster (1980), Webster et al. (1982), Summers et al. (1988), Crooker et al. (1991), Hunter et al. (1993), and NRC (1996).

Implant Effects on Energy Requirements. Information regarding the influence of growth-enhancing implants on energy requirements is limited. Energy requirements for growth, based on energy content of gain, were determined in trials using cattle receiving growth-enhancing hormones (NRC, 1984). Therefore, net energy requirements should be applicable for estrogen-implanted cattle. The NRC (1996) proposed the concept that addition of trenbolone acetate to the estrogen implant should reduce net energy requirements for growth by an additional 5%. In contrast, not using estrogenic implants has been reported to increase the net energy requirements for gain by

either 5% (NRC, 1984) or 4% (Oltjen et al., 1986) due to increased fat deposition. Above and beyond these estimates, in trials involving steers, maintenance energy requirements, based on body weight changes of limit-fed cattle, were decreased 10% by a trenbolone acetate implant (Hunter and Magner, 1990a); this reduction was attributed to a decrease in protein turnover (Hunter and Vercoe, 1987). Hunter and Vercoe (1987) also noted that when a low-protein roughage diet was fed, trenbolone acetate implants decreased voluntary feed intake by 15%. Hunter and Magner (1990b) attributed this decrease to an insufficient nitrogen supply that limited digestibility of organic matter. Hunter and Magner (1990b) concluded that trenbolone acetate implants reduced DM intake, organic matter passage rate (as a result of reduced urea synthesis in the rumen, 0.8 vs 1.2 g/h), and urea recycling (0.8 vs 1.1 g/h) to the rumen. On a side note, if implants decrease protein turnover (Hunter and Vercoe, 1987), protein requirements (g/d) might be reduced, but if protein intake were not altered, excess protein would be available as a source of energy. However, if cattle receiving anabolic implants deposit more protein each day, they would have greater daily protein requirements than those not implanted. Fuller (1968) reported that pigs fed a low (2%) protein diet required almost twice as much food to maintain bodyweight as pigs fed a high (25%) protein diet and attributed this difference to body composition changes. Interestingly, the percentage body fat of pigs fed the low protein diet nearly doubled, while that of animals consuming the high protein diet was reduced to one twentieth of the initial value (Fuller, 1968). These data could be interpreted to suggest that the amount of energy

required to maintain body weight would increase in a protein deficiency (Armstrong and Blaxter, 1984). Consequently, if an implant (trenbolone acetate) decreased protein turnover and protein requirements, this would decrease maintenance energy requirements of cattle fed a low protein diet.

Rumsey and Bond (1972) first documented that estrogen appeared to increase basal metabolic rate of heifers administered diethylstilbestrol (DES); heart beat rate was increased by 5.9%. In a similar trial, heart beat rate was increased 5.8% by feeding DES to steers (Rumsey et al., 1973) and weight loss was greater during periods of limited energy intake for those steers that were fed DES (Oltjen et al., 1973). Based on these data, Rumsey et al. (1980) concluded that the use of anabolic implants containing estrogen increased maintenance energy requirements by 4.3%. By extrapolation from curves relating weight gain to feed intake, Solis et al. (1989) concluded that steers implanted with either zeranol or estradiol plus progesterone required 3.5% more energy to meet their maintenance requirements than non-implanted steers. In contrast, implants reduced the amount of energy required for a unit of weight gain by 13.8%. These changes in energy requirements for maintenance and gain were suggested to reflect alterations in body composition (Solis et al., 1989). Rumsey et al. (1999) concluded that increasing energetic density of the diet would not compensate for inadequate protein; thus, optimum response to anabolic implants requires adequate dietary protein intake. Rumsey and Hammond (1990) suggested that when energy intake was not sufficient to meet maintenance energy requirements, estrogenic implants increased energy requirements whereas when energy intake

exceeded maintenance requirements, estrogen implants increased both body weight gain and nitrogen retention. Recently, Hutcheson et al. (1997), using cloned steers, concluded estrogenic implants used alone or in combination with androgens reduced gastrointestinal tract weights; this, in turn, would be expected to decrease maintenance energy requirements. However, extrapolation of the Hutcheson et al. (1997) data to zero feed intake indicated that maintenance energy requirements were increased 3.5% by estrogenic implants. Perhaps an increased liver mass of the estrogen-implanted steers may have counterbalanced the theorized reduction in energy required for maintenance that should have resulted from the reduced gastrointestinal tract weight. Hutcheson et al. (1997) speculated that overall changes observed in visceral organ mass in estrogen-implanted cattle were not large enough to affect basal energy expenditures. Nontheless, the greater liver mass might possibly explain why estrogenic implants increased energy requirements, especially if the liver's contribution to total energy expenditures (18% in rats according to Webster, 1980) were considered. Whether growth-enhancing implants increase liver mass of limit-fed cattle similar to rapidly growing cattle is not known.

Ionophore Effects on Energy Requirements. Data evaluating the effects of ionophores on maintenance energy requirements are very limited. To date, effects of ionophore feeding on maintenance have been measured using linear and semilog/linear methods for calculating energy parameters. Using this technique, Byers (1980) reported that monensin increased apparent efficiency of

energy used for maintenance by 5.7% but did not affect the efficiency of energy use for growth. This could indicate that monensin decreased the animal's energy expenditure for maintenance or that monensin increased the efficiency at which dietary energy was converted to net energy or both. Similarly, Delfino et al. (1988) reported that lasalocid increased the efficiency of dietary net energy use for maintenance by 10 to 21% and agreed that the efficiency for which dietary net energy was used for gain was not affected. Results of these studies combined with those of Goodrich et al. (1984) and others have resulted in the general recommendation (NRC, 1996) that net energy required for maintenance of a diet is decreased by 12% when an ionophore (monensin) is added to the diet.

It is not clear why ionophores might increase efficiency of dietary energy usage for maintenance but not gain. For a detailed review of ionophore types and their modes of action, readers are referred to Owens et al. (1991). Presumably, monensin alters energy availability or the efficiency of energy use by altering the microbial population so that methane loss is reduced (Thornton and Owens, 1981). Thus, monensin decreases the amount of dietary energy required for maintenance by reducing energy losses associated with ruminal fermentation and therefore less energy is "wasted". Such a change should increase both NEm and NEg of the diet, not just NEm. Rumpler et al. (1986) indicated that the reduction in methane production associated with feeding monensin was only temporary and did not persist for 56 days. Direct measurements of methane loss have confirmed that in the longer term methane loss was not reduced when monensin was fed even though propionate

production was increased (Richardson, 1996). Stoichiometrically, the only logical explanation for an increased propionate production with no reduction in methane is that extent of ruminal fermentation must have been increased when monensin was fed. Wampler et al. (1998) concluded that increasing concentrations of laidlomycin propionate and monensin decreased bacterial cell yield, supporting results previously reported by Poos et al. (1979) and Zinn et al. (1994) that feeding monensin decreased efficiency of microbial protein synthesis in the rumen. Nevertheless, most researchers would suggest that the efficiency enhancement attributable to the feeding of monensin may be due to alteration of volatile fatty acid composition, specifically increasing the propionate:acetate ratio (Bergen and Bates, 1984; Schelling, 1984; Galyean and Owens, 1988; Russell, 1997) while decreasing methane production in the rumen (Schelling, 1984; Galyean and Owens, 1988; Russell, 1997). If propionate is used more efficiently than acetate for growth or maintenance (Blaxter, 1967), an increased propionate:acetate ratio should improve metabolic efficiency and decrease energy losses. Later studies indicated that acetate was used inefficiently only when propionate supply was very low (Orskov et al., 1979). If indeed acetate is used inefficiently only when the propionate:acetate ratio is very low, as with roughage-based diets fed at low levels of feed intake, then ionophores would improve energetic efficiency more when energy intakes (and the propionate:acetate ratios) are low.

Because gram positive bacteria are suppressed when monensin is fed, another potential mode through which monensin might function is by reducing the

number of bacteria considered to be "leaches" in the rumen. If fewer microbes were present in the rumen, efficiency of growth would be improved. Visek (1978) noted that the mass of protein in the gut and rate of turnover of the gut was much less for "germ-free" rats than that in the viscera of animals with a normal intestinal flow. Thus, if monensin suppressed the presence of gram-positive bacteria (Chen and Wolin, 1979; Russell, 1987; Russell, 1997) and this, in turn, reduced turnover of the digestive tract, less energy would be required to maintain the microbial population in the rumen. However, this would only be the case if the improvement in efficiency due to reduced visceral mass turnover was greater than the decreased efficiency of microbial growth in the rumen associated with feeding monensin (Poos et al., 1979; Zinn et al., 1994).

Growing and Finishing

Overview of Factors Affecting Rate and Efficiency of Gain. The economics of beef cattle production depend heavily on performance of animals during growth, especially during the finishing period. Greater daily gains reduce the time needed to achieve an acceptable carcass weight increasing the potential for positive economic returns. Improving efficiency also can reduce production costs by reducing the amount of feed required for each unit of live weight gain. Based on the increasing prevalence of marketing on the basis of carcass weight and grade rather than live weight, gain and efficiency must be considered on a carcass weight rather than a live weight basis. Owens et al. (1995) reviewed

various aspects of growth and development of feedlot cattle and concluded that changes in body composition can make carcass weight gain deviate markedly from live weight gain. Owens et al. (1995) summarized that efficiency of fat accretion was approximately 1.7 times that of protein (energetic basis). But, because lean contains approximately 75% water compared with 10% for fat (NRC, 1984), lean tissue gain was four times more efficient than fat tissue accretion.

Generally, as feed intake increases rate of gain increases. For a detailed review of factors affecting feed intake, readers are encouraged to read the proceedings of two symposia edited by Owens (1986, 1995). Numerous factors have been shown to affect gain and efficiency. Effects of management (Moody et al., 1970; Ridenour et al., 1982; Lunt and Orme, 1987; King et al., 1993; Van Koevering et al., 1995; Wagner et al., 1998), diet composition and grain processing (Ferrell et al., 1978; Harrison et al., 1978; Owens et al., 1993; Bartle, et al., 1994; 1996; Milton et al., 1997), gender (Champagne et al., 1969; Thrift et al., 1970; Gregory and Ford, 1983), genetics (Gregory et al., 1994; Marshall, 1994; Vieselmeyer et al., 1996), and health (Wittum et al., 1996; Bryant et al., 1996; Gardner et al., 1999) on performance should be reviewed for further details.

Effect of Implants on Gain and Efficiency. Although this review will not discuss mechanisms of action, readers are encouraged to read Trenkle (1997) and Dayton (1997) if interested in "mechanisms of action" of estrogens and

androgens on performance. An expansive symposium that reviewed the effects of implants on performance and carcass value of beef cattle was conducted in 1996; for a complete review of implant effects on cattle performance, readers are referred to Owens (1997). In one article of that symposium, Kuhl (1997) suggested that animal response to estrogenic and androgenic implants depends upon growth rate (stocker cattle must be gaining greater than .32 to .45 kg) and/or plane of nutrition (energy consumption should exceed 1.5 times maintenance requirements) in order for implants to elicit a weight gain response. That restricted energy intake will reduce weight gain response from implants is not surprising because estrogen implants generally increase feed intake markedly, and if intake is not increased due to feed shortage or restriction, this benefit will not be realized. For cattle gaining little or no live weight, most or all of the absorbed energy will be expended for maintenance. In trials with steers, Rumsey et al. (1980) suggested that estrogen implants increased maintenance energy requirements by 4.3% (Rumsey et al., 1980). In contrast, an androgenic implant, 300 mg trenbolone acetate has been suggested to decrease maintenance energy requirements by 10% (Hunter and Magner, 1990). These values indicate that for cattle with a low rate of gain and restricted access to feed, estrogen would be deleterious whereas 300 mg trenbolone would be beneficial! Indeed, limit-fed steers that were losing weight lost 0.39 kg more each day when they received an estrogen implant (Oltjen et al., 1973). In contrast, steers that received 300 mg trenbolone acetate lost 0.22 kg less each day than non-implanted steers (Hunter and Magner, 1990). Mader et al. (1997) indicated that

administering estrogen implants to stocker cattle before they entered the feedlot reduced the response to estrogen implants given during the feedlot period. Hence, background also may influence the degree of implant response observed. This concern may or may not apply to combination (estrogen plus androgen) implants that are used extensively today for feedlot cattle.

Extensive feedlot research with cattle has shown that the use of implants during the finishing period will increase average daily gains and, in some instances, enhance feed efficiencies though results can differ with implant type, dosage, and time of administration. These same factors can substantially impact carcass grade traits. In an expansive review of implant effects on performance, carcass traits, and meat tenderness of feedlot steers, Duckett et al. (1996, 1997) summarized that ADG was increased 18% when cattle were implanted as compared to those not implanted. However, responses differed with the specific implant protocol. Among the comparisons of implants administered once during the feeding period, combination (strong estrogen plus androgen) implants resulted in the greatest daily gains. Androgen implants alone, though increasing ADG of heifers, did not increase ADG of steers (Duckett et al., 1997). Interestingly, implant regimes that utilized repeated implants of the same composition (re-implants) further increased daily gains whether assessed on a live weight or a carcass weight basis. Repeated combination implants of strong estrogen and androgen proved to be the most beneficial from a weight gain aspect, followed closely by repeated strong estrogen implants. Repeated

implants of androgen and mild estrogen did not enhance daily gain above that of non-implanted feedlot steers (Duckett et al., 1997).

Effect of Ionophores on Rate and Efficiency of Gain. The ionophore monensin has been reviewed in detail; Goodrich et al. (1984) and Raun et al. (1976) reviewed effects of monensin on beef cattle performance, Bergen and Bates (1984) reviewed monensin's mode of improving production efficiency, and Van Amburgh (1997) reviewed effects on growth and lactation. However, other ionophores (lasalocid, salinomycin, laidlomycin propionate, and lysocellin) have not been researched as thoroughly. An extensive review of all ionophores and their effects on metabolism, growth, and body composition, was conducted by Owens et al. (1991). In the review of Goodrich et al. (1984), which involved summarizing performance data of 228 trials (over 11,000 cattle), cattle fed diets containing monensin gained 1.6% more weight and consumed 6.4% less dry matter. Combined, these values indicate that monensin improved gain:feed ratio by 7.5%. Goodrich et al. (1984) also concluded that the performance benefits from ionophores were additive to that attained from estrogenic implants.

Carcass Characteristics

Overview of Factors Affecting Carcass Characteristics. Numerous factors can influence carcass characteristics. Owens and Gardner (2000) recently reviewed the association between various management factors (effect of initial

weight, time-on-feed, age at harvest) and nutritional factors (concentrate level, crude protein concentration and source, fat supplementation, ionophore presence) on carcass measurements. Gardner and Dolezal (1996) reviewed factors associated with management, gender and age-class, cattle type, and health on carcass characteristics. For more extensive details of time-on-feed effects on carcass traits, readers are referred to Dolezal et al. (1982), Williams et al. (1989), May et al. (1992), and Van Koevering et al. (1995). Although the effect of gender on carcass traits is minimal, pregnancy can have a negative impact on carcass measurements (Kreikemeier and Unruh, 1993; Waggoner et al., 1989), as can age class, especially for heifers and cows (Shackelford et al., 1995; Field, 1996). Genetic composition and cattle type have been criticized recently for their contribution to adverse effects on carcass quality and lean meat yield in reports by Cundiff et al. (1993), Marshall (1994), Wheeler et al. (1996), Vieselmeyer et al. (1996), and Gwartney et al. (1996). Although cattlemen have discounted non-thrifty cattle for their lack of performance, not until recently (Gardner et al., 1999) has the impact of health and respiratory disease on carcass traits been quantified.

Effect of Implants on Carcass Characteristics. Producers that retain ownership of their calves through the feedlot are concerned that using implants prior to feedlot placement may have adverse effects on both feedlot performance and on carcass value. Although carryover effects of implants administered during the growing phase on feedlot performance and carcass merit have been

documented (Mader, 1997), greater research attention is needed to determine lifetime implant effects on performance, carcass merit, and consumer desirability. The economic impact of carryover effects is of interest both for producers who maintain ownership of cattle through the feedlot and for feedlots purchasing cattle so that incoming cattle can be valued accordingly.

Carcass value is the multiple of carcass weight and carcass quality (price per hundred pounds). Although implants administered during the feedlot phase of production usually increase carcass weight, implants may have adverse effects on two different indices of carcass quality -- marbling and maturity -- and components of consumer interest -- meat palatability. An expansive review of implant effects on performance, carcass traits, and meat tenderness of feedlot steers was recently compiled by Duckett et al. (1996, 1997). In brief, this study documented that dressing percentage, fat thickness, percentage kidney, pelvic, and heart fat, yield grade, marbling score, incidence of dark cutters, and the percentage of carcasses grading U.S. Choice did not differ between implanted and non-implanted controls. However, Duckett et al. (1996) concluded implanting steers increased carcass weight by 5% and actual ribeye area by 3% compared to non-implanted controls; ribeye area per unit weight of carcass remained unchanged by implants. In a review of estrogenic and androgenic implant effects on carcass quality and maturity, Dolezal and Gardner (1997) concluded that implant type, dosage, and the time interval prior to harvest that implants are administered can dramatically influence marbling scores, skeletal maturity indices, and the percentage of carcasses grading U.S. Choice. Today,

as marketing of cattle on a carcass rather than a live weight basis becomes more prevalent, cattlemen must determine the appropriate implant strategy to balance the advantages in feedlot performance against potentially adverse effects of implants on carcass and meat quality if profitability is to be maximized.

Paisley et al. (1999), in research conducted after the Duckett et al. (1996) review, indicated that implants containing estrogen, administered during the growing phase and more than 270 days prior to harvest, advanced carcass maturity scores. Samber et al. (1996) noted that the single factor about implants that had the greatest impact on carcass traits was the number of implants administered; three successive implants markedly reduced carcass quality grade. Although effects of implants on lean color have not been studied extensively to date, comments from packing plant supervisors indicate that the appearance of the ribeye today has a "mousy brown" tinge that was not apparent in the past when less potent implants were used. Effects of implant type and timing on carcass and meat quality need to be quantified so that shorter-term economic and longer-term effects on consumer acceptance of beef can be predicted.

Effect of Ionophores on Carcass Characteristics. As noted by Goodrich et al. (1984) and Owens et al. (1991), very little work has examined the effects of ionophores on carcass composition and meat quality. Goodrich et al. (1984) concluded that feeding monensin did not affect any carcass measurements. Owens et al. (1991) indicated that dressing percentage, ribeye area per kg carcass weight, and quality grade appeared to be decreased when monensin

was fed, whereas subcutaneous fat thickness was increased. Similar to the conclusion of Goodrich et al. (1984), Owens and Gardner (2000) noted that the addition of various ionophores to the diet had very minimal impact on carcass measurements, except that carcass weight was increased slightly as a result of monensin supplementation. However, each of these reviewers cautioned readers that insufficient data concerning the effects of ionophores on carcass measurements and other meat quality attributes have been collected to draw justified conclusions.

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CHAPTER III

IMPACT OF IMPLANTS AND MONENSIN ON WEIGHT GAIN BY STEERS LIMIT-FED TO MAINTAIN WEIGHT

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ABSTRACT: Steer calves (n = 187; 293 ± 17.8 kg) of similar background were limit-fed a 50% concentrate diet (NEm = 1.71 Mcal/kg DM) at their estimated maintenance requirement (3.27 kg DM daily) for 56 d. Steers, blocked by weight, were assigned to one of 32 pens (six head/pen) with eight pens assigned to each of four implant regimes: none; 20 mg estradiol benzoate and 200 mg progesterone (estrogen); 140 mg trenbolone acetate (TBA); or 20 mg estradiol benzoate and 200 mg progesterone plus 140 mg trenbolone acetate. Within each implant regimen, four pens of steers were fed diets with no monensin while the other four pens received the same diet with 33 ppm monensin added. Feed supply was adjusted weekly in an attempt to achieve zero weight gain; non-implanted steers fed the control diet had an ADG of 0.17 kg for the total trial. Compared with non-implanted steers, those receiving TBA alone or in combination with estrogen had greater ($P < .05$) weight gain by d 7 of the study and those receiving estrogen had greater ($P < .04$) weight retention by d 28.

Over the 56-d trial period, TBA-containing implants increased gain by 11.0 kg ($P < .001$) and estrogen-containing implants increased gain by 7.5 kg ($P < .03$), with effects of TBA and estrogen implants being additive. Steers fed diets containing monensin exhibited a weight gain advantage ($P < .06$) starting on d 21; by d 56, steers receiving monensin had gained 4.0 kg more weight ($P < .04$) than steers not receiving monensin. No significant interactions between monensin and implant presence or implant type were detected. Neither implants nor feeding monensin altered fat thickness (mean = 1.88 mm; determined using ultrasound) at d 56 nor did they alter hip height measurements (mean increase = 3.2 cm) during the trial. Results indicate that weight gain of limit-fed steers can be increased by including monensin in the diet and by administering estrogenic or TBA implants. Based on net energy calculations, the amount of feed required for weight maintenance of these steers was reduced 5.7% by feeding monensin, 12% with an estrogen implant, 20% with a TBA implant, and 35% with a combination implant.

Key Words: Implants, Ionophores, Maintenance, Energy, Beef

Introduction

In the United States, most calves are "grown" or "backgrounded" for a period of time before they enter the feedlot. Some of these calves are "dry wintered" on dormant native or improved warm season grasses. During dormancy, these grasses are of low nutritive value, and, therefore, calves gain at very slow rates. These calves may or may not be implanted with growth stimulants. Although not substantiated by research, many producers and

researchers believe that estrogenic implants are not beneficial for cattle gaining less than 0.32 to 0.45 kg/d (Kuhl, 1997). If calves are implanted, should they be given an estrogenic implant, an androgenic implant (trenbolone), or a combination of these two? Limited research suggests that trenbolone acetate (TBA; 300 mg) implants may decrease energy requirements for maintenance (Hunter and Magner, 1990a), whereas, estrogenic implants have been suggested to increase maintenance energy requirements (Rumsey et al., 1980).

Steers backgrounded on low-quality forage typically are fed a protein supplement but not an ionophore. Although research evaluating the effects of ionophores on maintenance energy requirements is lacking, the NRC (1996), based on extrapolation from feeding trials, suggests that monensin will decrease maintenance energy requirements by 12% and thereby should be useful for calves not gaining weight or those gaining at a very slow rate. This study was designed to measure weight retention responses to various implants and to monensin supplementation by steers limit-fed in an attempt to maintain their body weight.

Materials and Methods

Routine livestock handling methods as outlined in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Consortium, 1988) were used in this research.

Weight Maintenance Determination

Medium frame Angus crossbred steer calves (n = 187; 9 mo of age) weighing approximately 293 kg and originating from herds of similar genetic

potential in the upper Midwest U.S. were transported to the Willard Sparks Beef Research Center, Stillwater, OK on November 23, 1998. Approximately 30 d prior to shipment, each steer was vaccinated with a killed virus infectious bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD), bovine respiratory syncytial virus (BRSV), parainfluenza (PI_3) vaccine combination (Triangle 4, Fort Dodge Animal Health, Overland Park, KS). Upon arrival, each steer was weighed, re-vaccinated with a killed virus IBR, BVD, BRSV, PI_3 vaccine combination (Triangle 4, Fort Dodge Animal Health, Overland Park, KS), treated for internal and external parasites with moxidectin (Cydectin, Fort Dodge Animal Health, Overland Park, KS), and identified with a numbered ear tag. Steers were re-vaccinated with a modified live virus IBR, BVD, BRSV, parainfluenza (PI_3) vaccine combination (BRSV Vac 4, Bayer Animal Health, Shawnee, KS) 10 and 28 d post-arrival due to persistent respiratory disease episodes. The trial was initiated on December 21, 1998, 28 d after the steers had arrived and after the steers had recovered from transport stress; the trial was completed in February 1999. Steers were blocked by weight into one of four blocks and assigned randomly within weight block to one of eight pens for a total of 32 pens (five or six steers/pen). Eight pens of steer calves were assigned randomly to each of four implant regimens: none; 20 mg estradiol benzoate and 200 mg progesterone (estrogen; Component-S®, VetLife, Overland Park, KS); 140 mg trenbolone acetate (TBA; Component-T-S®, VetLife, Overland Park, KS); or 20 mg estradiol benzoate and 200 mg progesterone plus 140 mg trenbolone acetate (Est+TBA; Component-S® plus Component-T-S®, VetLife, Overland Park, KS).

Steers that received the combination of estrogen plus TBA received one implant containing 20 mg estradiol benzoate and 200 mg progesterone in the left ear and one implant containing 140 mg trenbolone acetate in the right ear. Within each implant regimen, four of the eight pens received diets with no added monensin whereas the other four pens received the same diet with 33 ppm (DM basis) monensin (Rumensin®, Elanco Animal Health, Greenfield, IN) added. During this 56 d trial, steers were fed an average of 3.27 kg DM daily of a diet that consisted of 50% concentrate and 50% roughage (Table 1) at 1500. Initial and final weights were calculated as the mean weight taken on two consecutive days prior to feeding. Steers were weighed at 0800 every 7 d throughout the trial; feed delivery was adjusted every week in an attempt to achieve zero body weight change (maintenance) for the non-implanted steers consuming feed with no monensin added. Because steers were limit-fed, weights reported are full weights with no adjustment being made for fill. Hip heights were measured initially and at the conclusion of the 56-d weight maintenance period. Fat thickness at the $12^{th}/13^{th}$ rib interface was determined via ultrasound on d 56 (Aloka 210, Corometrics Medical Systems, Inc., Wallingford, CT) using a five MHz probe (Corometrics Medical Systems, Inc., Wallingford, CT). Fecal samples gathered from each pen on d 22 were analyzed for the presence of cocci using the Wisconsin Modified Sugar technique (Cox and Todd, 1962).

Cause of death was determined for the two steers that died during the feeding period. One steer died of acidosis on d 50 and the other steer died of heart problems on d 16. Two additional steers were removed from the trial on d

14 and one steer on d 21 due to lameness. Feed intake was adjusted accordingly so that steers remaining in those pens received the same quantity of feed on a per head basis.

Estimation of Energetic Efficiency

All calculations were based on mean pen weights because feed intake of individual animals was not measured. For these calculations, shrunk body weight (SBW) and empty body weight (EBW) for the mean animal in each pen was calculated from live weight (LW) as SBW = 0.95*LW and EBW = 0.89*SBW as specified by NRC (1996); mean feeding weight was the mean of initial SBW and final SBW. Net energy required for maintenance (Mcal/d) was estimated as $0.077*SBW^{0.75}$. Net energy required for gain, the equivalent of energy retention, was calculated using NRC (1996) equations as $0.0635*EQEBW^{0.75}*EBG^{1.097}$. Empty body gain (EBG) was calculated as 0.956*SBG (shrunk body gain). Equivalent empty body weight (EQEBW) was calculated as 0.891*SBW*(SRW/FSBW). Standard reference weight (SRW) was 478 kg, an assumed final shrunk market weight of medium frame steers (NRC, 1996). Final shrunk body weight (FSBW) was estimated to be 543 kg, the mean shrunk harvest weight of steers in the present trial following a 125 d finishing period at which time mean marbling score averaged 414 (with a marbling score of 400 being the minimum marbling score required for carcasses to qualify for the U.S. Choice quality grade).

Three different calculation methods were used to estimate effects of implants or monensin on energetic efficiency. The first estimation was a direct

solution achieved through iteratively estimating NEm and NEg from performance and feed intake. Hereafter, these realized estimates are denoted as RNEm and RNEg. The second and third estimations were based on the assumption that NEg of the diet was not altered by treatments so that the full treatment effect would be attributed to a changed NEm of the diet. The second estimate of NEm, hereafter called CNEm, was calculated assuming that NEg was equal to RNEg calculated iteratively from performance and feed intake of the estrogen-implanted steers not fed monensin as described above. The third estimation of NEm, hereafter called TNEm, was calculated assuming that NEg of the diet was equal to the tabular value for NEg (TNEg) of the diet based on NRC (1996) values for individual feed ingredients. Relative impact of individual treatments on each of these NEm estimates, relative to the estrogen-implanted steers not fed monensin, then was calculated.

In the first case (RNEm), metabolizable energy values for the diet fed to steers in each implant and feeding treatment were calculated iteratively using NRC (1996) equations for NEm and NEg requirements and mean daily dry matter intake; RNEm and RNEg were calculated from these ME values. These values, when divided by RNEm and RNEg values for the estrogen-only implanted cattle not fed monensin (baseline steers from NRC, 1996), represent the ratios in efficiency of net energy used by the test steers assuming that efficiency of both RNEm and RNEg was altered by implants and monensin.

The second and third NEm estimates were based on the assumption that treatments altered NEm but not NEg, as presumed by NRC (1996). The second

estimate of NEm, namely CNEm (calculated net energy required for maintenance), was estimated using RNEg from the direct solution mentioned above. Then, feed used for gain was calculated by dividing retained energy (NRC, 1996) by RNEg for the estrogen-implanted steers not fed monensin; residual DM presumably was used for maintenance, so that CNEm of the diet was considered to equal the maintenance energy needed (NRC, 1996) divided by the residual DM. For the third solution, TNEg was substituted for RNEg in the calculations above and TNEm was calculated exactly like CNEm above. The RNEm, CNEm, and TNEm values, divided by the matching NEm values for implanted steers not fed monensin, were used as estimates of efficiency for use of NEm by individual pens of steers.

As an example of these calculations, steers receiving the combination (Est+TBA) implant but not monensin had initial and final shrunk weights of 292.9 kg and 314.2 kg, respectively. [Note: In all reported tables, values are means across either implant regime or monensin level, whereas in this example, values are for a specific implant × ionophore combination; thus, values in this example calculation will not match tabular values for individual treatments.] These values yield mean shrunk and empty body weights of 303.5 kg and 270.4 kg and shrunk and empty daily body weight gains of 0.381 and 0.364 kg. This means that energy retained daily was 1.327 Mcal and the maintenance net energy requirement was 5.59 Mcal/d. Based on these figures and iteration against a dry matter intake of 3.941 kg, these steers were obtaining 1.904 Mcal of RNEm/kg and 1.263 Mcal of RNEg/kg diet. However, steers implanted with estrogen

alone, by iteration, had obtained 1.708 Mcal RNEm and 1.091 Mcal RNEg from each kg of diet consumed. This means that averaged across maintenance and gain, the addition of a TBA implant had increased efficiency of RNEm use by 11.4% (1.904/1.708) vs estrogen alone.

Based on the RNEg of the estrogen-implanted steers (1.091 Mcal/kg) or the TNEg of the diet (1.10 Mcal/kg), the amount of feed that was used for energy gain (1.327 Mcal/d) would have been 1.217 and 1.207 kg daily, respectively. From the total daily supply of dry matter, 3.941 kg, this leaves 2.724 and 2.734 kg, respectively, for maintenance. Dividing the NEm requirement of these steers (5.59 Mcal/d) by these amounts of feed indicates that feed DM supplied 2.070 Mcal CNEm/kg or 2.061 Mcal TNEm/kg, respectively. Compared to the 1.708 Mcal CNEm/kg or 1.751 Mcal TNEm/kg values based on similar calculations for the estrogen-implanted steers, this means that addition of TBA to the estrogen implant had improved efficiency of CNEm use by 17.5% (2.070/1.708) or of TNEm use by 17.8% (2.061/1.751), respectively. Averaged across CNEm and TNEm, the mean NEm benefit from the additional TBA implant was 17.65%.

The percentage adjustments in maintenance for each of the pens were analyzed statistically to examine the magnitude of the impact of various implants or of monensin on maintenance energy requirements. All calculations are based on the assumption that body composition and specific organ weights were not altered differentially by implants or monensin.

Statistical Analysis

Data were analyzed as a 4 x 2 factorial (four implants and two levels of monensin) using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with initial weight included as a blocking factor and pen serving as the experimental unit. Because no significant interactions ($P > .43$) between implant and ionophore were detected, only main effects will be reported. Treatment sums of squares for implant type were separated using non-orthogonal contrasts. For implant type, these included comparisons of 1) non-implanted control steers vs the average for all implanted steers (none vs estrogen, TBA, and estrogen+TBA); 2) the average for steers not receiving an estrogen implant vs the average of those implanted with estrogen either alone or in combination with TBA (none and TBA vs estrogen and estrogen+TBA); 3) the average of steers not receiving TBA vs the average of those implanted either with TBA alone or combined with estrogen (none and estrogen vs TBA and estrogen+TBA), and 4) the interaction between TBA and estrogen implants. Monensin effects were compared across all implant regimes. Absolute significance levels were calculated and reported.

Results and Discussion

Among the performance measurements, none of the interactions between TBA and estrogen or between monensin feeding and implant presence, type, or interaction of types were significant ($P > .43$). Consequently, as mentioned previously, only main effects will be provided and discussed. All steers lost weight during the first 14 d of the limit-fed period. These losses might be expected for cattle placed on a weight maintenance diet and can be attributed to

a decrease in digestive tract contents (Carstens et al., 1991) as well as some reduction in intestinal/digestive organ mass (Koong et al., 1982; Drouillard et al., 1991). In addition, environmental conditions during this 2-wk period were not favorable (average temperature -12°C, wind chill -23°C), which would have increased maintenance energy requirements beyond that required for maintenance under thermoneutral conditions (Fox et al., 1988; Birkelo et al., 1991; Fox and Tylutki, 1998). As often is observed with energy restriction trials, even though feed intake was maintained at the same low level for several weeks, these limit-fed steers later tended to re-gain weight. This observation supports the concept that ruminants can adapt to a period of energy shortage by reducing the amount of dietary energy expended for weight maintenance (Ledger and Sayers, 1977; Armstrong and Blaxter, 1984). No significant interactions between implant type and monensin supplementation were detected. Because this interaction was not significant, perhaps the benefits from implants and monensin are additive; consequently, implant and monensin effects will be discussed separately.

Hip height was measured as an index of skeletal growth. Hip height increases were not different (P = .81) among treatments; regardless of treatment, hip height increased an average of 3.30 cm during the 56 d maintenance period. This indicates that, even though weight gain was minimal, skeletal growth continued. Although it was not measured at the start of the trial, ultrasound-estimated fat thickness on d 56 was not altered (P = .66) by treatment. This suggests that neither implants nor feeding monensin had markedly altered body

composition. These data support the contention of Hutcheson et al. (1997) that anabolic implants increase growth by accelerating nutrient deposition as protein but not at the expense of fat. Fecal samples for all steers obtained on d 22 were negative for the presence of coccidial oocysts indicating that the weight gain differences with monensin feeding could not be attributed to control of coccidiosis. At no time during the trial were symptoms of coccidiosis noted with any of the steers. To illustrate responses, differences in unshrunk mean live weight gains between steers with various implants (Figure 1) and steers fed monensin or the control diet (Figure 2) are presented.

Implant Response

The trial was designed so that each pen of steers within a weight block received the same amount of feed. Consequently, effects of anabolic implants on dry matter intake were controlled; as a result, feed efficiency differences are reflected directly by differences in weight gain. Already on d 7, an effect of implants on weight gain were detected ($P < .05$; Table 2). The average weight of steers that received TBA implants, either alone or in combination with estrogen (TBA and Est+TBA), increased more than the average of the non-implanted steers and those steers that received an estrogen implant only (none and estrogen). This numeric advantage in weight was maintained and tended to increase throughout the trial. For the total 56 d trial, steers implanted with TBA gained 11.0 kg more weight than steers not receiving TBA, indicating that TBA implants may be reducing maintenance energy requirements, probably due to a decrease in protein turnover (Hunter and Vercoe, 1987). Since fat thickness as

well as hip height measurements were not different at the conclusion of the trial (Table 2), this weight advantage also might be attributed to increased protein gain as noted by Perry et al. (1991), Nichols (1991), and Hutcheson et al. (1997). For the first 21-d of the trial, weight increases were no greater for steers that received estrogen than for non-implanted steers. However, starting on d 28, estrogen-implanted steers had greater ($P < .05$) weight gain than control steers. At the end of the 56 d limit-fed period, steers with estrogen implants had gained 7.5 kg more live weight than steers not implanted. Paisley et al. (1999) concluded that estrogen-containing implants were beneficial to stocker cattle grazing dormant native range and gaining less than 0.35 kg daily. However, these data conflict with statements by Kuhl (1997), that cattle gaining less than 0.32 to 0.45 kg per day, and Oltjen et al. (1973), working with cattle that were losing weight (1.51 kg daily), who both concluded cattle with low rates of weight gain did not benefit from the use of anabolic implants. Because responses in weight gain to the estrogen implant were reasonably small, it is not surprising that field trial reviews have detected no weight gain response to estrogen implants among cattle with low rates of gain, particularly among grazing cattle where pasture conditions and feed supply, feed intakes, and weighing conditions can vary drastically. The benefits of estrogen appeared numerically additive to those of TBA (Figure 1), and the interaction was not significant ($P = .61$); steers implanted with estrogen plus TBA gained more weight than those steers implanted with TBA alone. If the mechanisms of action of androgens differ from

that of estrogens as indicated by Trenkle (1997) and Dayton et al. (1997), additive effects of TBA and estrogen would not be surprising.

In contrast to suggestions by Rumsey et al. (1980) and Solis et al. (1989) that estrogen implants increase maintenance energy requirements, weight gain of limit-fed steers was greater for steers given estrogen implants in this trial. This suggests that the amount of feed required for weight maintenance of these immature steers was reduced by estrogen implants. Lemieux et al. (1988) detected no effect of estrogen implants on the efficiency of metabolizable energy used by steers for maintenance or gain; however, Lemieux et al. (1988) suggested that NEg requirements were reduced for cattle implanted with estradiol plus progesterone. Hutcheson et al. (1997) estimated that NEg requirements were reduced by 19% when estrogenic or combination implants were administered to Brangus steers.

Net energy calculations for steers are presented in Table 3. Although feed intakes, body weights, and maintenance energy requirements, as calculated from mean body weight, were not altered by implants, all other measurements including weight gain, retained energy, and estimates of RNEm and RNEg were greater ($P < .01$) for implanted than non-implanted steers. To estimate effects of implants on efficiency of energy use, effects of implants on NEm values were calculated relative to non-implanted cattle. For example, RNEm values for control, estrogen implanted, TBA implanted, and combination implanted steers were 1.62, 1.75, 1.84, and 1.96 Mcal/d. The average response to estrogen implants was [(1.75-1.62)/1.62+(1.96-1.84)/1.84]/2 Mcal/d. Based on such

calculations, efficiency of use of feed available for maintenance, based on RNEm, CNEm, and TNEm values, relative to non-implanted cattle, was improved 7.3, 12.2, and 12.2% ($P < .01$) by estrogen implants, 12.8. 19.6, and 20.3% ($P < .01$) by TBA implants, and 21.0, 34.2, and 35.0% by the combination of the two implants. Averaged across CNEm and TNEm estimates, estrogen implants improved energetic efficiency by 12%, TBA implants improved energetic efficiency by 20%, and the combination by 35%. The increase in RNEm by the combination implant (Est+TBA) was within 3% of the sum of the individual implants indicating that responses to TBA and estrogen were additive. These increases in estimates of NEm support the conclusions of Hunter and Magner (1990a,b) as well as those of Hunter et al. (1993a); maintenance requirements, as measured by weight loss of animals maintained under very sparse grazing conditions, were decreased 10% when cattle were implanted with 300 mg trenbolone acetate (Hunter et al., 1993a).

Why implants would improve efficiency of weight maintenance of limit-fed steers is not known. Hunter et al. (1993b) suggested protein turnover might be decreased by TBA implants. Finished steers typically have greater muscle mass if they have received implants and the lean-to-fat ratio often is greater for implanted than non-implanted cattle (Duckett et al., 1996). If maintenance energy expenditures are related to lean body mass, implants would be expected to increase, not to decrease, the maintenance requirement per unit of body weight. However, if protein turnover is decreased or if implants induce short-term increases in protein and water retention or reductions in the size of high

maintenance internal organs (liver and digestive tract), implants could result in short-term weight gains. Further experiments are needed to examine what mechanisms might be responsible for these changes and determine whether these weight changes truly represent alterations in energetic efficiency.

Monensin Response

Weights, daily gains, feed efficiency, hip height, and $12^{th}/13^{th}$ rib fat thickness data are presented in Table 4. Although all steers were fed 3.28 kg DM daily, steers fed the diet containing 33 ppm monensin gained 4.0 kg more live weight during the 56 d weight maintenance period than those fed the diet with no monensin added. A summary of feedlot performance trials indicated that monensin addition increased ADG by 1.6% while decreasing DM intake by 6.4% for a feed efficiency improvement of 7.5% (Goodrich et al., 1984). However, studies that have directly evaluated the effects of ionophores on maintenance energy utilization are limited. Effects of ionophore feeding on maintenance energy requirements have been measured using linear or semilog/linear methods for calculating energy retention at various DM intake levels. Using this technique, Byers (1980) reported that when 33 ppm monensin was fed, efficiency of energy used for maintenance was increased by 5.7%; these researchers suggested that monensin feeding did not affect the efficiency of energy use for growth. Using a similar approach, Delfino et al. (1988) reported that lasalocid increased net energy for maintenance values of the diet by 10 to 21% and concurred that efficiency of net energy use for gain was not affected. Results from net energy studies in which feed intake was controlled might produce

biased results if test compounds alter ruminal methane loss because the fractional loss of energy as methane is greater at low DM intake. Consequently, if monensin acts through reducing methanogenesis (Thornton and Owens, 1981), response should be greater when DM intake is low. This would cause response in NEm to be overestimated and response in NEg to be underestimated.

Diets containing monensin tended to increase empty body gain (Figure 1). As calculated from mean empty body weight, weight gain, and feed intake, maintenance requirements were decreased in this trial by a mean of 5.7% (4.6% for RNEm, 6.6% for CNEm, and 6.1% for TNEm) through including 33 ppm monensin in the diet, but statistical significance of this improvement depends on the method by which maintenance requirements were calculated. Monensin tended to improve ($P < .06$) both RNEm and RNEg, but the effect of monensin on CNEm and TNEm was not significant statistically ($P < .11$). This reflects variation in efficiency of NEg use among pens of steers being fed monensin due either to implants or to slight differences in body weight among the blocks. Nevertheless, no interaction between implants and monensin in calculated net energy values was detected ($P > .64$). Effect of weight block on RNEg approached significance ($P < .12$), and when starting weight was included as a covariant rather than as a blocking factor, RNEm, RNEg, and efficiency of energy use for maintenance were all greater ($P < .05$) for steers fed diets containing monensin. Why monensin might decrease maintenance requirements is not fully clear. Visek (1978) noted that the mass of protein and rate of protein turnover in the gut was less for "germ-free" rats than normal rats. Thus, if monensin suppressed the

presence of gram-positive bacteria (Chen and Wolin, 1979; Russell, 1987; Russell, 1997) and reduced turnover of the digestive tract, it could reduce maintenance energy expenditures. Secondly, through altering the microbial population to produce propionate and reduce methane loss (Thornton and Owens, 1981), more of the fermented energy would be available to the animal for production. However, Rumpler et al. (1986) indicated that the methane reduction is temporary and would not persist for 56 d. Nevertheless, most researchers would suggest that the efficiency enhancement attributable to the feeding of monensin may be due to alteration of volatile fatty acid composition, specifically increasing the propionate:acetate ratio (Bergen and Bates, 1984; Schelling, 1984; Galyean and Owens, 1988; Russell, 1997) while decreasing methane production in the rumen (Schelling, 1984; Galyean and Owens, 1988; Russell, 1997). Some research suggests that in the longer term methane loss was not reduced when monensin was fed even though propionate production was increased (Richardson, 1996). Based on stoichiometric principles, the only way that monensin could increase the ruminal production of glucogenic VFAs without increasing ruminal methane production would be for monensin to increase the extent of organic matter fermented in the rumen. Though monensin will decrease ruminal dilution rate (Adams et al., 1981), shifting site of digestion from the postruminal tract to the rumen would not be expected to increase energetic efficiency (Owens, 1986) unless the shift was from the large rather than the small intestine back to the rumen.

NRC (1996) suggests that feeding monensin will decrease the maintenance energy requirement by 12%; that value is considerably greater than the 5 to 6% values noted in the current trial. Considering that monensin presumably acts to decrease pre-absorption loss of energy, one would expect that supply of energy for both NEm and NEg would be increased. If both NEm and NEg of the diet were increased in this trial, a 5% increase in both could explain the response from including monensin in the diet. Nevertheless, from this study alone, it is impossible to ascertain whether changes should be attributed to differences in NEm or NEg supplied by the diet or efficiency of use or a decrease in the requirement for NEm or NEg.

Maintenance studies using animals with different metabolic sizes might be used to differentiate between NEm and NEg effects of specific implants or feed additives. Because both monensin and implants increased weight gain when feed intake was restricted and equalized, benefits from these compounds cannot be fully attributed to alterations in feed intake often observed when these compounds are supplied.

Implications

Feeding monensin increased weight gain of steers fed at a maintenance level of energy, indicating that monensin decreases the amount of dietary energy required for weight maintenance. Implants had more immediate and dramatic effects on increasing body weight. Whether short-term alterations in the partitioning of nutrients (decreased lipid and increased protein) or altered metabolism (e.g., reducing protein turnover or visceral mass or enhancing lipid

mobilization) are responsible for the reduction in the quantity of feed needed for weight maintenance of implanted steers is not known. Results indicate that even when daily gains of steers are very low (0.17 kg), weight maintenance can be enhanced both by estrogenic or TBA implants and by including monensin in the diet.

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Table 1. Feedstuff and energy content (DM basis of diet) fed to steers during a 56-day weight-maintenance period

	Ration	
Ingredient, %	No Monensin	Monensin
Alfalfa, dehydrated	49.91	49.91
Corn grain, whole shelled	44.92	44.92
Cottonseed meal, 44% CP	4.13	4.13
Wheat middlings	0.65	0.63
Salt, trace mineralized	0.33	0.33
Monensin, 80 g/0.454 kg	**0.00**	**0.02**
Tylosin, 40 g/0.454 kg	0.03	0.03
Vitamin A, 30,000 IU/g	0.03	0.03

---------- Calculated Analysis (NRC, 1996) ----------

Nutrient	Diet Composition, DM basis
NEm, Mcal/kg	1.71
NEg, Mcal/kg	1.10
Crude protein, %	15.05
Crude fiber, %	14.60
Potassium, %	1.22
Calcium, %	0.96
Phosphorus, %	0.33

Table 2. Least squares means for rate and efficiency of gain of non-implanted and implanted steers during a 56-day weight maintenance period

Item	Implant regimen[a]				SE	Effect[b]
	Control	Estrogen	TBA	Est+TBA		
Pens	8	8	8	8		
Weight, kg						
Initial	293	295	291	293	2.10	--
Final	303	307	310	316	1.83	TB, E, I
Daily gain, kg/d						
0 – 7	-1.47	-1.30	-0.81	-0.81	0.20	TB, I
0 – 14	-1.62	-1.66	-1.39	-1.32	0.16	tb
0 – 21	-0.10	-0.05	0.18	0.24	0.07	tb, I
0 – 28	0.08	0.23	0.37	0.44	0.05	TB, E, I
0 – 35	0.04	0.16	0.27	0.36	0.04	TB, E, I
0 – 42	0.06	0.13	0.23	0.30	0.04	TB, e, I
0 – 49	0.11	0.15	0.28	0.35	0.04	TB, I
0 – 56	0.17	0.22	0.33	0.41	0.03	TB, E, I
Hip height, cm						
Day 1	117.35	117.30	117.48	117.40	0.48	--
Day 56	120.70	120.32	120.75	120.55	0.36	--
Fat thickness[c], mm	1.99	1.78	1.76	1.84	0.15	--

[a] Implant regimen: Control = no implant; Estrogen = 20 mg estradiol benzoate and 200 mg progesterone; TBA = 140 mg trenbolone acetate; Est+TBA = 20 mg estradiol benzoate and 200 mg progesterone plus 140 mg trenbolone acetate.

[b] Effect:
I = Control vs Estrogen, TBA, and Est+TBA ($P < .05$);
E = Estrogen and Est+TBA vs Control and TBA ($P < .05$);
TB =TBA and Est+TBA vs Control and Estrogen ($P < .05$);
e = Estrogen and Est+TBA vs Control and TBA ($P < .10$);
tb = TBA and Est+TBA vs Control and Estrogen ($P < .10$).

[c] Fat thickness was determined using ultrasound and was estimated at the $12^{th}/13^{th}$ rib juncture.

Table 3. The effects of different anabolic implants on energy retention and maintenance energy requirements for non-implanted and implanted steers during a 56-day weight maintenance period

Item[b]	Implant regimen[a]				SE	Effect[c]
	Control	Estrogen	TBA	Est+TBA		
Pens	8	8	8	8		
Mean EBW	258.5	262.8	260.6	264.8	6.65	--
EBG. kg/d	0.16	0.24	0.32	0.39	0.03	I, e, TB
DMI, kg/d	3.83	3.84	3.83	3.84	0.09	--
Maintenance energy, Mcal/d	5.41	5.47	5.44	5.51	0.10	--
RE, Mcal/d	0.49	0.83	1.06	1.39	0.14	I, e, TB
RNEg, Mcal/kg	1.01	1.13	1.21	1.31	0.04	I, E, TB
NEm, Mcal/kg						
RNEm (Direct solution)	1.62	1.75	1.84	1.96	0.04	I, E, TB
CNEm (Based on RNEg)	1.61	1.80	1.92	2.16	0.07	I, E, TB
TNEm (Based on TNEg)	1.60	1.79	1.92	2.15	0.07	I, E, TB
Efficiency, % of estrogen implanted steers						
RNEm (Direct solutions)	94.8	102.4	107.9	114.8	2.39	I, E, TB
CNEm (Based on RNEg)	91.5	102.4	109.5	123.0	4.04	I, E, TB
TNEm (Based on TNEg)	91.6	102.4	109.4	122.8	3.98	I, E, TB

[a] Implant regimen: Control = no implant; Estrogen = 20 mg estradiol benzoate and 200 mg progesterone; TBA = 140 mg trenbolone acetate; Est+TBA = 20 mg estradiol benzoate and 200 mg progesterone plus 140 mg trenbolone acetate.

[b] EBW = empty body weight, EBG = empty body gain, DMI = dry matter intake, MEN = maintenance energy needed, RE = retained energy.

[c] Effect:
I = Control vs Estrogen, TBA, and Est+TBA ($P < .05$);
E = Estrogen and Est+TBA vs Control and TBA ($P < .05$); e = Estrogen and Est+TBA vs Control and TBA ($P < .10$);
TB = TBA and Est+TBA vs Control and Estrogen ($P < .05$)

Table 4. Least squares means for rate and efficiency of gain of steers during a 56-day weight maintenance period with or without monensin in the diet

	Supplement[a]			
Trait	No Monensin	Monensin	SE	*P* =
Pens	16	16		
Weight, kg				
Initial	293	293	1.46	0.74
Final	307	311	1.39	0.04
Daily gain, kg/d				
0 – 7	-1.09	-1.11	0.14	0.91
0 – 14	-1.47	-1.52	0.11	0.76
0 – 21	0.00	0.13	0.05	0.07
0 – 28	0.22	0.34	0.04	0.03
0 – 35	0.15	0.27	0.03	0.01
0 – 42	0.14	0.22	0.03	0.02
0 – 49	0.18	0.26	0.03	0.03
0 – 56	0.25	0.31	0.02	0.04
Hip height, cm				
Day 1	117.35	117.35	0.35	0.98
Day 56	120.65	120.65	0.26	0.98
Fat thickness, mm[b]	1.81	1.88	0.12	0.66

[a] Supplement was formulated to contain 33 ppm monensin.

[b] Fat thickness at the $12^{th}/13^{th}$ rib juncture determined using ultrasound.

Table 5. The effects of monensin on energy retention and maintenance energy requirements for steers during a 56-day weight maintenance period

	Supplement[a]			
Trait[b]	No Monensin	Monensin	SE	*P* =
Pens	16	16	--	--
Mean EBW	264.2	259.1	4.70	0.46
EBG. kg/d	0.25	0.30	0.02	0.16
DMI, kg/d	3.88	3.79	0.07	0.29
Maintenance energy, Mcal/d	5.50	5.42	0.07	0.47
RE, Mcal/d	0.88	1.01	0.10	0.35
RNEg, Mcal/kg	1.13	1.20	0.03	0.05
NEm, Mcal/kg				
RNEm (Direct solution)	1.75	1.83	0.03	0.05
CNEm (Based on RNEg)	1.81	1.93	0.05	0.11
TNEm (Based on TNEg	1.81	1.92	0.05	0.11
Efficiency, % of estrogen implanted steers				
RNEm (Direct solution)	102.5	107.4	1.69	0.05
CNEm (Based on RNEg)	103.2	109.9	2.85	0.11
TNEm (Based on TNEg	103.2	109.9	2.81	0.11

[a] Supplement was formulated to contain 33 ppm monensin.

[b] EBW = empty body weight, EBG = empty body gain, DMI = dry matter intake, MEN = maintenance energy needed, RE = retained energy.

Figure 1. Weight difference between implanted and non-implanted steers during a 56-day weight maintenance period

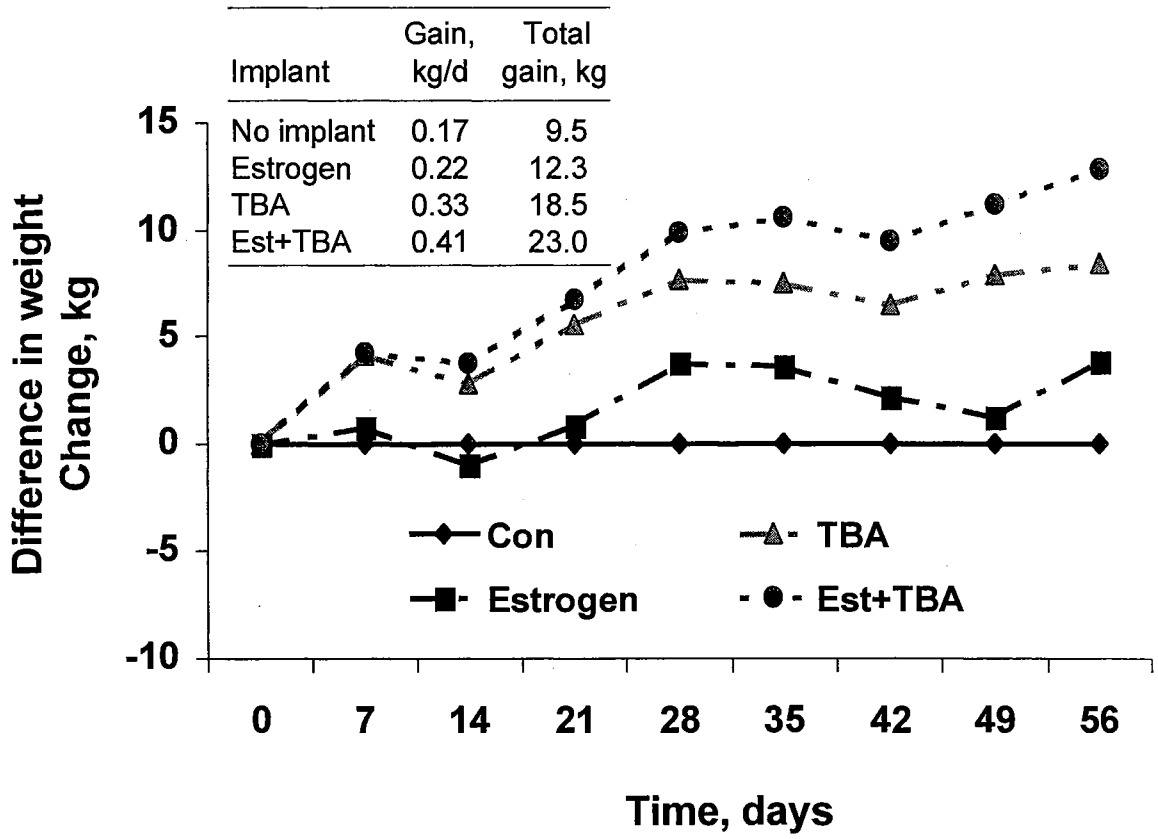
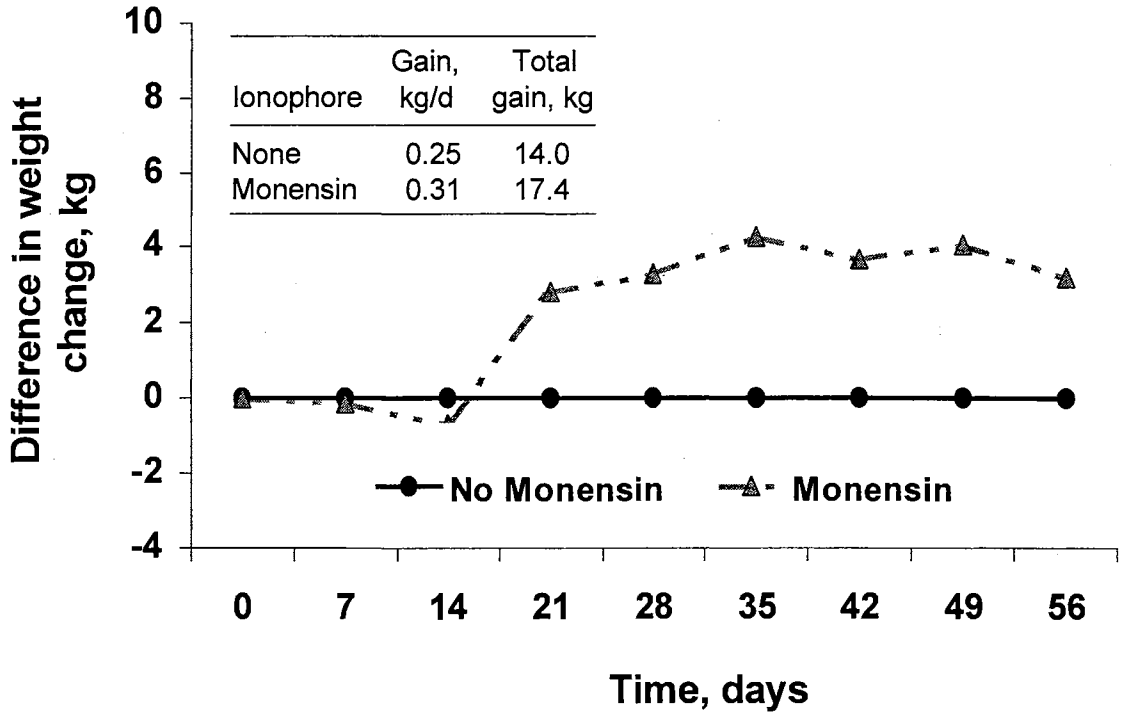


Figure 2. Weight difference between steers during a 56-day weight maintenance period fed diets with or without monensin



CHAPTER IV

CARRYOVER EFFECTS OF IMPLANTS AND MONENSIN ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS

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ABSTRACT: Steer calves (n = 182; 32 pens; 309 ± 19.1 kg) that previously had received either no implant (control), 20 mg estradiol benzoate and 200 mg progesterone, 140 mg trenbolone acetate, or 20 mg estradiol benzoate and 200 mg progesterone plus 140 mg trenbolone acetate and that had been limit-fed a 50% concentrate diet (either with or without 33 ppm monensin) for 56 d were utilized to determine the carryover effects of implant type and monensin effects on feedlot performance and carcass characteristics. Following a 56-d period of weight maintenance, all steers were adapted to an 87% corn-based diet (NEm = 2.02, NEg = 1.37 Mcal/kg DM); all steers received an implant (120 mg trenbolone acetate plus 24 mg estradiol) on d 28 of the finishing period and steers were fed the finishing diet an average of 125 d. Much of the weight benefit gained from estrogenic implants during the weight maintenance phase was retained through the feedlot period while none of the additional gain from TBA implants was retained. Steers previously implanted with estrogen consumed more (P = .07)

feed during the finishing period but were less (P = .05) efficient than steers that had not been implanted. Although steers that had previously received TBA alone or in combination were heavier (P < .01) at the beginning of the finishing period, ADG and gain:feed of these steers was lower (P = .07) than for steers that had not received TBA previously. Steers that had previously received estrogen alone or in combination with TBA were heavier (P = .04) than those cattle that had not previously received estrogen upon conclusion of the finishing period. Surprisingly, steers implanted previously with TBA tended (P = .07) to be shorter (hip height was reduced) at harvest than steers not previously implanted with TBA. As a result of a greater (P = .02) dressing percentage, steers that were implanted previously with estrogen yielded heavier (P < .01) carcass weights than those not implanted previously; this partially explains their greater (P = .04) *longissimus* area. Steers that had previously received an estrogen-containing implant tended to have more external (P = .09) as well as internal (P < .01) fat. Thus, carcasses from steers that received estrogen prior to finishing had less (P = .09) desirable (higher numeric) yield grades than those carcasses from steers which had not previously received estrogen. Also, the use of estrogen-containing implants accelerated (P < .05) skeletal maturity indices, indicating that estrogen may be responsible for the negative effects of implants on carcass maturity scores. Results indicate implant regimen administered prior to the onset of finishing can substantially impact feedlot performance and carcass characteristics of steers.

Key Words: Implants, Ionophores, Steers, Feedlot, Performance, Carcass

Introduction

Effects of anabolic implants on feedlot performance and carcass attributes were reviewed by Duckett et al. (1997). Averaged across all implant types, anabolic agents administered during the finishing period increased daily gain by 18%; this was the result of two factors -- greater DM consumption (6%) and improved growth efficiency (8% less feed required per unit of live weight gain). Carcasses from implanted steers were heavier than their non-implanted counterparts; as a result, their carcasses had larger *longissimus* areas. However, implanting at the start of the finishing period had negative effects on both carcass maturity indices as well as USDA quality grade. Both implant type (estrogen, androgen, estrogen plus androgen) and frequency, through altering hormonal status, probably can alter both live performance and carcass characteristics. Even though anabolic agents administered during the finishing period have received the greatest scrutiny regarding their adverse effects on carcass traits, implanting cattle prior to the finishing phase also may be involved with the erosion of carcass quality in the beef industry reported by Boleman et al. (1998). Paisley et al. (1999) noted that anabolic implants administered more than nine months prior to feedlot placement adversely affected skeletal maturity, carcass quality, and therefore, carcass value. Only a few other studies, including those reported by Mader et al. (1985), Simms et al. (1988), Mader et al. (1994), Mader (1994), and Frankhouser et al. (1997), have examined carryover effects of implant type and aggressiveness during the growing phase on feedlot performance and carcass attributes.

Effects of ionophores on feedlot performance have been evaluated or reviewed by Goodrich et al. (1984), Galyean and Owens, (1988), and Owens et al. (1991). Owens et al. (1991) examined the effects of feeding ionophores on carcass attributes, while Owens and Gardner (1999) reviewed the effects of ionophores on carcass, meat quality, and sensory attributes. However, effects of providing dietary ionophores during backgrounding on subsequent feedlot performance have not been studied. The objectives of this study were to 1) determine the carryover or residual effects of anabolic implant type and of monensin supplementation during a restricted growth period on subsequent feedlot performance and carcass attributes and 2) determine if restricting intake for a short time affected subsequent performance and carcass measurements relative to calves that had been fed ad libitum.

Materials and Methods

This research was conducted following routine livestock handling methods as outlined in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Consortium, 1988).

Medium frame Angus crossbred steer calves (n = 182; 9 mo of age) weighing approximately 309 kg were limit-fed a 50% concentrate (NEm = 1.76 Mcal/kg DM) diet for a low rate of gain (mean ADG of 0.28 kg) for 56 d. Cattle management practices for steers used in the present trial were described by Gardner et al. (2000) and are summarized briefly below. In the previous trial, steers had been stratified by weight and assigned randomly to one of 32 pens with five or six steers per pen. Eight pens of calves were assigned to each of

four implant regimens: none; 20 mg estradiol benzoate and 200 mg progesterone (Component-S®, VetLife, Overland Park, KS); 140 mg trenbolone acetate (Component-T-S®, VetLife, Overland Park, KS); or 20 mg estradiol benzoate and 200 mg progesterone plus 140 mg trenbolone acetate (Component-S® plus Component-T-S®, VetLife, Overland Park, KS). Within each implant regimen, four pens were fed diets with no added monensin whereas the other four pens received the same diet with 33 ppm monensin added (Rumensin™, Elanco, Inc., Lilly Research Laboratories, Greenfield, IN).

Following the period of restricted feed intake, steers were gradually adapted (12 d) to a diet that contained whole corn (NEm = 2.12, NEg = 1.36 Mcal/kg DM; Table 1) and 33 ppm monensin added (Rumensin™, Elanco, Inc., Lilly Research Laboratories, Greenfield, IN) which was fed for the duration of the finishing period (average of 125 d). The quantity of feed offered was increased gradually until feed supply exceeded feed intake. In addition to the finishing ration, one pound of native prairie grass hay was fed immediately prior to ration delivery for 28 d due to persistent ruminal distension. This distension may have been a result of the fact that steers had trained themselves to eat very rapidly during the weight maintenance trial. Cattle were fed twice daily at approximately 0700 and 1550. On d 28 of the high concentrate finishing period (97 d prior to harvest), all steers received a second implant that contained 120 mg trenbolone acetate plus 24 mg estradiol-17β (Component-TES®, VetLife, Overland Park, KS).

In addition to the 32 pens of steers that previously had been limit-fed the 50% diet for a low rate of gain, four pens of steers (five or six steers per pen) that had not been restricted (fed ad libitum) during the initial 56 d were implanted with 20 mg estradiol benzoate and 200 mg progesterone (Component-S®, VetLife, Overland Park, KS). These four pens of ad libitum-fed steers were adapted gradually over 18 d to the same whole corn (NEm = 2.12, NEg = 1.36 Mcal/kg DM) finishing diet that contained 33 ppm monensin (Rumensin™, Elanco, Inc., Lilly Research Laboratories, Greenfield, IN). To clarify, during the 56-d "limit fed" period, these ad libitum fed steers had not been fed the restricted diet but rather were "worked up" to the finishing diet shown in Table 1. Steers were managed similarly to those previously fed the restricted diet except that these four pens of steers received a second implant with 120 mg trenbolone acetate plus 24 mg estradiol (Component-TES®, VetLife, Overland Park, KS) 105 d prior to harvest.

After initiation of this finishing trial (February 15, 1999), all steers were weighed unshrunk at 28-d intervals prior to their 0700 feeding until completion of the trial in June 1999. Feedlot daily gain was calculated from initial individual animal weights and final individual weights (based on the assumption that fill was equal to 4% of full body weight). Hip height measurements as well as fat thickness at the $12^{th}/13^{th}$ rib interface also were determined at 28 d intervals for the duration of the trial. Fat thickness was determined using an Aloka ultrasound machine (Aloka 210, Corometrics Medical Systems, Inc., Wallingford, CT) equipped with a five MHz probe (Corometrics Medical Systems, Inc., Wallingford, CT). On d 162 (22 calves fed ad libitum), 175 (81 previously restricted steers

comprising the two heavy weight replications), and 189 (81 previously restricted steers comprising the two light weight replications) steers were transported and harvested at Excel Corporation in Dodge City, KS. Carcasses were chilled at 0°C for approximately 36-h, after which USDA quality and yield grade (USDA, 1997) carcass measurements were obtained by University personnel.

As all cattle evaluated to determine carryover effects of implant type and monensin had been implanted and fed monensin during the finishing period, carryover effects from the previous trial were analyzed as a 4 x 2 factorial (four implants and two levels of monensin) using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with implant status and monensin feeding being class variables and weight replication from the previous trial serving as a blocking factor; pen served as the experimental unit. No interaction between the use of TBA and estrogen implants was detected for any of the measured parameters even though effects of anabolic implant presence and type were detected. Consequently, simple effects due to implant type prior to finishing will be reported. Treatment sums of squares for previous implant type were separated using non-orthogonal contrasts that compared 1) non-implanted control vs the mean for all implanted steers, 2) steers implanted with estrogen alone or in combination vs steers not receiving an estrogenic implant, and 3) steers implanted with TBA alone or in combination vs steers not receiving a TBA implant. Because implant type during the restricted feeding period affected ($P <$ .05) final weights, initial weights in the present trial differed. Thus, data were analyzed using initial weight as a covariant; also, carcass data were analyzed

using carcass weight and fat thickness as covariants. The use of these covariants revealed significance levels similar to those observed based on unaltered simple effects; consequently, all data reported are for simple effects due to implant type without covariant adjustment.

To determine the effects of feed management (restricted vs ad libitum), only steers that had been implanted initially with the same initial implants (20 mg estradiol benzoate and 200 mg progesterone) and fed monensin were evaluated. Thus, only eight pens (four restricted and four ad libitum) were used to examine carryover effects of severely restricting feed intake during a pre-feedlot period. Data were analyzed as a randomized block (paired T-test) using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with feed management serving as the class variable and initial weight as a blocking factor; pen served as the experimental unit. Because steers fed ad libitum had greater external fat thickness than those fed the restricted diet, carcass data were also analyzed using fat thickness as a covariant. The use of fat thickness as a covariant revealed significance levels similar to those observed based on unaltered simple effects, so all means reported are for simple effects due to feed management without covariant adjustments.

Results and Discussion

Mean, minimum, and maximum values for selected live performance and carcass characteristics for pens used to evaluate "carryover effects" are presented in Table 2. Mean initial live weight for the steers was 309 kg and mean weight at slaughter was 543 kg for an average daily gain of 1.87 kg. Daily

dry matter consumed averaged 9.00 kg, which resulted in 0.21 kg of cattle gain for each kg of feed consumed. Pen mean dressing percentages ranged from 58.5 to 64.1% and averaged 61.2%; these values are low relative to the industry average, probably because of abnormally large rumen fill due to feeding of a whole corn-based diet. Saleable carcass weight averaged 332 kg. Mean adjusted fat thickness was 11.79 mm; combined with other carcass yield grade parameters, this resulted in a mean yield grade of 3.0 as calculated from carcass measurements. Marbling score ranged from slight to modest, with mean marbling score being 14 percentage points into the small marbling category.

Implant Response

As a result of the design of the previous trial in which these steers were used, initial weights attributable to implant regimen prior to finishing differed (Table 3); steers that were not implanted were lighter ($P < .05$) than those that were implanted; cattle implanted with TBA were heavier ($P < .05$) than those not implanted with TBA, and those implanted with an estrogen-containing implant were heavier ($P < .05$) than those not receiving estrogen. Despite being the heaviest at initiation of the finishing period, steers that received TBA gained 8 kg less ($P = .06$) during the finishing period than steers that had not received TBA as a result of lower ($P = .07$) ADG throughout the finishing period. Cattle that had not received an implant prior to finishing remained ($P < .05$) lighter than those that had received an estrogen implant (538 kg vs 548 kg), indicating that the weight advantage gained from estrogen implants during backgrounding was retained throughout the finishing period. Paisley et al. (1999) similarly noted the

5 kg weight advantage for steers implanted with estrogen implants and wintered on dormant native range was maintained throughout the subsequent summer grazing and feedlot phases. Gill et al. (1986) and Simms et al. (1988) also have documented that the weight gain advantage achieved when suckling calves were implanted with estrogenic implants was maintained throughout the growing and finishing phases.

By d 84 of the feeding period and averaged for the total finishing period, feed intake for those steers that had received estrogenic implants was enhanced. Averaged over the entire finishing period, steers that received implants consumed 0.23 kg (2.6%) more (P = .07) DM daily than those not implanted, while steers that had previously received an estrogen implant consumed 0.30 kg (3.4%) more (P < .01) DM daily than steers that had not been previously implanted with estrogen. A summary of 77 research trials (Duckett et al., 1997) indicated that when an implant was administered at the start of the finishing period, DM intake of steers was increased by an average of 9.1% and when an estrogen implant was given, DM intake was increased an average of 11.5%. In those trials, control steers presumably had not received an implant prior to their backgrounding period whereas in the current trial, all steers were implanted at the start of the finishing period and the 2 to 3% increase in DM intake is an estimate of the carryover effect from a previous period. Whether this increase can be ascribed to residual differences in body composition or other factors is not clear. However, because daily gain was not increased by previous implant even though feed intake was increased, the steers that had received an implant prior

to finishing gained less (P = .05) efficiently than steers not previously implanted. Numerically, this reduction in efficiency must be subdivided; it can be attributed fully to the TBA implants, not to estrogenic implants. Based on a three-trial summary, Mader (1997) likewise concluded that cattle administered successive implants of 36 mg zeranol during the growing or growing and suckling phases of growth required more DM per unit of live weight gain than those cattle which had not previously received implants (gain:feed increases of 5.9 and 4.7%, respectively) again due to 3.4 to 3.9% higher DM intake without a compensating increase (-2.3 and -.8%, respectively) in gain. The use of TBA prior to finishing in the present study resulted in cattle that were 3.9% less (P = .02) efficient at converting feed to gain than those not receiving TBA due to a 3.4% slower gain while consuming 0.30% more feed. Duckett et al. (1997) noted steers that received a single androgenic implant at the onset of finishing had no advantage in daily gain when compared to non-implanted steers but required more (10.9%) feed per kg of live weight gain than non-implanted controls. In this study, NEm and NEg values, as calculated from steer performance and feed intake, tended to be slightly lower for steers implanted previously with TBA.

Hip height measurements (Table 3) did not (P = .74) differ among treatment groups at the initiation of the finishing period. However, by d 56, skeletal growth, as estimated by hip height, for steers implanted previously with TBA tended (P = .06) to be reduced; on d 112, TBA implanted steers were 1.3 cm shorter (P = .07) than steers that had not received a TBA implant in the previous study. Fat thickness, determined throughout the finishing phase using

ultrasound, did not (P = .68) reveal any differences between non-implanted and implanted steers prior to finishing when averaged across implant types. Carcasses from those cattle which had previously received an estrogen-containing implant had 6.3% more subcutaneous (P = .09) and 6.8% more internal (P < .01) fat than carcasses from steers that had not received an estrogen implant previously (Table 4). Similar effects on fat deposition were noted for estrogen-implanted steers that were implanted while grazing dormant native range (Paisley et al., 1999); at harvest, those steers that had been implanted previously had 6.4% more external fat than steers that had not been implanted previously.

Steers that had received an implant prior to finishing (estrogen, TBA, Est+TBA) yielded 9 kg (2.8%) heavier (P < .01) carcasses that tended to have more external (P = .13) and had more internal (P < .01) fat plus a 2.53 cm^2 (3.3%) larger (P = .04) *longissimus* area than those steers that had not been implanted during the previous 56 d weight maintenance period. With *longissimus* area counterbalancing the increased fat depth, the difference in the expected percentage yields of boneless, closely-trimmed round, loin, rib, and chuck due to implant regimen prior to finishing was not (P = .68) significant. Duckett et al. (1996) summarized that anabolic implants increased carcass weight by 16.9 kg (5.5%) and *longissimus* area by 2.88 cm^2 (3.8%) as compared to carcasses from non-implanted steers. Data from the present study convincingly indicate that the use of implants during a period prior to finishing will hasten (P < .05)

physiological maturity indices, as documented in other trials (Apple et al., 1991; Hardt et al., 1995; Foutz et al., 1997; Gardner et al., 1999; Paisley et al., 1999).

Carryover effects of implants on fat deposition and maturity differed with type of implant. The use of TBA prior to feedlot placement did not ($P > .29$) result in any noticeable carcass quality or yield trait effects, whereas estrogenic implants increased both fat deposition and skeletal maturity scores. Steers that received estrogenic anabolic agents prior to finishing tended ($P = .07$) to yield a greater percentage of live weight as carcass weight. When combined with their heavier ($P = .04$) final live weights, this advantage in dressing percentage resulted in estrogen-implanted steers yielding greater ($P < .01$) carcass weights than steers not receiving with estrogen-containing implants. Carcasses from estrogen-implanted steers had more ($P = .09$) subcutaneous fat and had a greater ($P < .01$) percentage of kidney, pelvic, and heart fat than carcasses from steers not receiving estrogen implants previously. However, because *longissimus* area per unit of carcass weight was sufficiently increased, yield grade was not ($P = .16$) altered due to the use of estrogenic implants. Steers that received an estrogenic implant had the most ($P < .01$) advanced skeletal and overall maturity scores even though lean maturity was not ($P = .51$) affected by the use of estrogen-containing implants. Neither implanting nor implant type significantly altered ($P = .74$ for implants; $P = .87$ for TBA; $P = .37$ for estrogen) marbling scores. However, those carcasses from steers that previously had received an estrogenic implant yielded the lowest percentage of U.S. Choice carcasses (58% for non-implanted; 58% for TBA implanted; 50% for estrogen

implanted). Thus, these data indicate that type of implant administered prior to finishing or at the start of the finishing period, as noted by Pritchard (1997), must be considered if one seeks maximum carcass quality (combination of youthful maturity and maximum marbling score).

In this study, implants were not removed at the start of the finishing period. Consequently, we cannot determine whether carryover effects are due to continued hormone release by the previous implants or to alterations in body composition or hormonal responsiveness induced by the earlier implants. The life span of implants, as judged by performance responses in previous research (Herschler et al., 1995; Gardner et al., 1999), should exceed 56 d, the length of the weight maintenance period in the present trial. Hence, continued hormonal release from previous implants would be expected for some time into the finishing period. As a result, implant carryover effects noted in the present trial may be less than studies in which the time interval between implants and feedlot entry is longer. To study residual effects independent of hormonal residues, removal of earlier implants (explanting) would have been necessary.

Monensin Response

Including monensin in the diet fed prior to the finishing period did not ($P >$ .31) significantly alter feedlot performance, hip height, or $12^{th}/13^{th}$ rib fat thickness (Table 5). Likewise, dressing percentage, carcass weight, *longissimus* area, yield grade ($P >$ .37), and maturity scores ($P =$ .20) did not differ (Table 6) between those steers that had received 33 ppm added monensin vs those that had not received monensin prior to the finishing phase. Interestingly, steers that

had received monensin for 56 d prior to the 125 d finishing period tended (P = .07) to have more external fat and to deposit more (P = .19) fat around the kidneys and heart, as well as in the pelvic cavity (Table 6). Although not statistically significant (P = .41), marbling scores followed a trend similar to that of other fat depots; steers previously fed monensin had numerically higher marbling scores than their contemporaries that were not fed monensin.

Feed Management Response

As a result of severely restricting feed intake, steers fed ad libitum were 110 kg heavier (P = .002) and had 3.52 cm greater (P = .006) fat thickness on d 56 than those whose feed intake had been restricted (Table 7). Even though steers "restricted" during the first 56 d tended (P = .186) to consume less feed from d 56 to completion of the finishing period (.77 kg daily, 7.9%), "restricted" steers tended (P = .154) to have greater daily gains (.27 kg, 17.0%) after the feed restriction period. Consequently, steers restricted for 56 d gained 27.2% (.044 kg) more weight for each kg of DM consumed than ad libitum fed steers. Results of the present trial support the conclusions of Hicks et al. (1990), Murphy and Loerch (1994), and Knoblich et al. (1997) that following a period of feed restriction, steers had improved gain:feed. As noted by Knoblich et al. (1997) and Loerch and Fluharty (1998), feed management practice did not (P > .70) affect any carcass quality measurements. Data from the present trial support the conclusion of Murphy and Loerch (1994) and Knoblich et al. (1997) that cattle whose intake had been restricted required more days on feed to reach a specific body condition. Similar to results reported by Knoblich et al. (1997) and Loerch

and Fluharty (1998), feeding strategy had little effect on carcass measurements, except that yield grade was lower (more desirable) for the "restricted" calves (P = .04; Table 8). The more desirable yield grade for "restricted" steers (3.08 vs 3.27) was a combined result of carcasses from "restricted" steers having numerically less fat (external and internal) and larger *longissimus* area per 100 kg carcass weight.

Implications

Presence and type of anabolic implants used two months prior to feedlot placement can influence feedlot performance, efficiency, and carcass merit. Weight gain benefits achieved through the use of estrogen-containing implants during a 56-d pre-feedlot phase were maintained throughout the feeding period. However, cattle that received estrogen implants prior to finishing ate more feed and gained only slightly faster during the finishing period. Steers that had received trenbolone implants prior to finishing tended to gain less rapidly and efficiently during the finishing period. Estrogen implants had negative carryover effects on carcass quality, increasing fat deposition both internally and externally and increasing bone maturity scores. Results indicate that implants used prior to finishing can have substantial effects on feedlot performance and carcass characteristics.

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Table 1. Feedstuff and energy content (DM basis) of diets fed during weight maintenance and subsequent finishing period

	Diet	
Ingredient, %	Weight maintenance ration [a]	Finishing ration
Alfalfa, dehydrated	49.91	
Cottonseed hulls		5.09
Corn grain, whole shelled	44.92	86.53
Cottonseed meal, 44% CP	4.13	5.09
Soybean meal, 47.7% CP		
Wheat middlings	0.65	1.01
Salt, trace mineralized	0.33	0.33
Monensin, 80 g/0.454 kg		0.02
Tylosin, 40 g/0.454 kg	0.03	0.011
Vitamin A, 30,000 IU/g	0.03	0.011
Limestone		1.13
NPN		0.45
Potassium chloride		0.34
Selenium-600		0.006
Manganous oxide		0.005
Zinc sulfate		0.003
Copper sulfate		0.001
---------- Calculated Analysis ----------		
Nutrient	Final Diet Composition	
NEm, Mcal/kg	1.71	2.02
NEg, Mcal/kg	1.10	1.37
Crude protein, %	15.05	11.88
Crude fiber, %	14.60	5.13
Potassium, %	1.22	0.67
Calcium, %	0.96	0.48
Phosphorus, %	0.33	0.33

[a] Feed restricted diet was formulated to contain either 33 ppm monensin or no monensin when fed for 56 d prior to feeding finishing ration.

Table 2. Pen means for selected live and carcass attributes evaluated to determine effect of implant type and monensin supplementation during a 56-day weight maintenance period prior to finishing on subsequent feedlot and carcass performance

Trait	Mean	Minimum	Maximum	SD
Initial weight, kg	309	280	349	19.13
Final weight, kg	543	505	591	21.06
ADG, kg/day	1.87	1.66	2.10	0.11
Daily DM intake, kg/day	9.00	7.93	10.12	0.47
Gain:Feed, kg/kg	0.21	0.19	0.23	0.01
Calculated NEm, Mcal/kg	2.22	2.02	2.40	0.09
Calculated NEg, Mcal/kg	1.53	1.36	1.68	0.08
Dressing percentage	61.18	58.45	64.11	1.11
Hot carcass wt. (HCW), kg	332	305	363	13.76
Fat thickness, mm	11.79	9.56	1.41	0.10
Longissimus area (LMA), cm^2	77.61	72.78	84.88	3.21
LMA/100 kg HCW	10.63	9.85	11.38	0.39
Internal fat (KPH), %	2.14	1.75	2.42	0.18
Yield grade	3.01	3.39	2.61	0.21
Maturity score[a]				
Skeletal	143	122	168	12.50
Lean	133	124	147	4.75
Overall	138	124	152	7.71
Marbling score[b]	414	360	513	37.14

[a] Maturity score: 100 to 199 = "A", between 9 and 30 months of age.

[b] Marbling score: 500 = "modest^{00}", the minimum required for U.S. Average Choice; 400 = "modest^{00}", the minimum required for U.S. Low Choice; 300 = "slight^{00}", the minimum required for U.S. Select.

Table 3. Least squares means for subsequent rate and efficiency of gain, hip height, and fat accretion during finishing due to anabolic implant type administered during a 56-day weight maintenance period

	Implant regimen[a] prior to finishing period					
Item	Control	Estrogen	TBA	Est+TBA	SE	Effect[b]
Pens	8	8	8	8		
Weight, kg						
Initial	303	307	310	316	1.96	I, TB, E
Day 28	338	339	341	354	5.02	tb
Day 56	407	411	409	417	3.82	--
Day 84	477	482	478	485	3.71	--
Day 112	522	535	523	536	4.36	E, i
Final	538	547	536	548	4.74	E
Total gain, kg	235	239	226	232	9.81	tb
Daily gain, kg/d						
0 – 28	1.25	1.13	1.10	1.36	0.15	--
29 – 56	2.48	2.56	2.44	2.27	0.14	--
56 – 84	2.49	2.54	2.48	2.40	0.05	--
85 – 112	1.59	1.90	1.61	1.82	0.09	I, e
0 – Finish	1.88	1.92	1.81	1.86	0.03	tb
Daily DM intake, kg/d						
0 – 28	5.65	5.55	5.67	5.71	0.11	--
29 – 56	8.47	8.57	8.55	8.54	0.05	--
57 – 84	10.74	11.16	10.76	11.14	0.11	I, E
85 – 112	10.90	11.67	11.00	11.53	0.21	I, E
0 – Finish	8.83	9.15	8.88	9.16	0.10	E, i

Gain:feed, kg/kg						
0 – 28	0.222	0.203	0.195	0.231	0.02	--
29 – 56	0.293	0.299	0.285	0.267	0.02	--
57 – 84	0.232	0.227	0.231	0.216	0.01	--
85 – 112	0.146	0.162	0.146	0.159	0.01	E
0 – Finish	0.213	0.210	0.204	0.203	0.01	I, TB
Calc. NEm, Mcal/kg	2.20	2.26	2.19	2.21	0.03	--
Calc. NEg, Mcal/kg	1.52	1.56	1.51	1.52	0.03	--
Hip height, cm						
Initial	120.7	120.4	120.9	120.7	0.38	--
Day 56	124.5	125.2	124.2	123.7	0.48	tb
Day 84	127.5	128.3	127.0	127.0	0.41	TB
Day 112	129.8	130.6	128.8	129.0	0.58	tb
Fat thickness[c], mm						
Initial	2.00	1.78	1.77	1.84	0.17	--
Day 56	3.95	3.37	3.77	3.47	0.19	E, i
Day 84	5.73	5.70	5.95	5.47	0.23	--
Day 112	8.54	8.20	8.25	8.61	0.26	--

[a] Implant regimen: Control = no implant; Estrogen = 20 mg estradiol benzoate and 200 mg progesterone; TBA = 140 mg trenbolone acetate; Est+TBA = 20 mg estradiol benzoate and 200 mg progesterone plus 140 mg trenbolone acetate.

[b] Effect:
I = Control vs Estrogen, TBA, and Est+TBA ($P < .05$);
E = Estrogen and Est+TBA vs Control and TBA ($P < .05$); e = Estrogen and Est+TBA vs Control and TBA ($P < .10$);
TB = TBA and Est+TBA vs Control and Estrogen ($P < .05$); tb = TBA and Est+TBA vs Control and Estrogen ($P < .10$).

[c] Fat thickness was determined using ultrasound and was estimated at the $12^{th}/13^{th}$ rib juncture.

Table 4. The effect of anabolic implant type administered during a 56-day weight maintenance period on subsequent carcass yield and quality attributes

Item	Implant regimen[a] prior to finishing period				SE	Effect[b]
	Control	Estrogen	TBA	Est+TBA		
Pens	8	8	8	8		
Dressing percentage	60.3	61.6	61.3	60.5	0.39	I, e
Hot carcass wt. (HCW), kg	325	337	328	337	2.69	I, E
Fat thickness, mm	11.36	11.95	11.67	12.20	0.03	e
Longissimus area, cm^2	75.7	78.4	78.2	78.1	0.97	I
Longissimus area/100 kg HCW	23.36	23.34	23.84	23.24	0.29	--
Internal fat (KPH), %	2.05	2.19	2.11	2.19	0.04	I, E
Yield grade	3.00	3.04	2.94	3.09	0.07	--
Maturity score[c]						
Skeletal	137	148	135	151	3.10	I, E
Lean	131	134	133	132	1.71	--
Overall	134	141	134	142	2.06	I, E
Marbling score[d]	418	408	422	408	13.07	--
Quality Grade						
Choice, %	58.33	49.17	64.58	52.08		
Select, %	39.17	48.33	33.33	43.75		
Standard, %	2.50	2.50	2.08	4.17		
Yield Grade						
1, %	2.50	4.16	4.58	0.00		
2, %	43.33	36.67	52.92	45.83		
3, %	52.08	52.08	42.50	49.17		
4, %	2.08	7.00	0.00	5.00		

[a] Implant regimen: Control = no implant; Estrogen = 20 mg estradiol benzoate and 200 mg progesterone; TBA = 140 mg trenbolone acetate; Est+TBA = 20 mg estradiol benzoate and 200 mg progesterone plus 140 mg trenbolone acetate.

[b] Effect:
I = Control vs Estrogen, TBA, and Est+TBA ($P < .05$);
E = Estrogen and Est+TBA vs Control and TBA ($P < .05$); e = Estrogen and Est+TBA vs Control and TBA ($P < .10$).

[c] Maturity score: 100 to 199 = "A", between 9 and 30 months of age.

[d] Marbling score: 400 = "small^{00}", the minimum required for U.S. Choice.

Table 5. Least squares means for subsequent rate and efficiency of gain, hip height, and fat accretion during finishing following a 56-day weight maintenance period in which monensin was either not included or included in the diet

	Supplement[a] fed prior to finishing period			
Trait	No Monensin	Monensin	SE	*P* =
Pens	16	16		
Weight, kg				
Initial	307	311	1.39	0.09
Day 28	344	342	3.55	0.71
Day 56	410	412	2.70	0.55
Day 84	478	483	2.63	0.29
Day 112	527	530	3.09	0.49
Final	541	543	3.36	0.73
Daily gain, kg/d				
0 – 28	1.31	1.12	0.11	0.23
29 – 56	2.36	2.51	0.10	0.30
57 – 84	2.45	2.51	0.04	0.26
85 – 112	1.75	1.71	0.06	0.72
0 – Finish	1.88	1.86	0.02	0.69
Daily DM intake, kg/d				
0 – 28	5.67	5.62	0.08	0.64
29 – 56	8.53	8.54	0.04	0.78
57 – 84	10.92	10.98	0.08	0.57
85 – 112	11.24	11.31	0.15	0.75
0 – Finish	8.98	9.03	0.07	0.65

Gain:Feed, kg/kg				
0 – 28	0.227	0.199	0.02	0.22
29 – 56	0.278	0.294	0.01	0.33
57 – 84	0.224	0.229	0.01	0.46
85 – 112	0.155	0.151	0.01	0.59
0 – Finish	0.209	0.206	0.01	0.39
Calculated NEm, Mcal/kg	2.21	2.22	0.02	0.98
Calculated NEg, Mcal/kg	1.53	1.53	0.02	0.98
Hip height, cm				
Initial	121.0	121.0	0.26	0.99
Day 56	124.0	124.0	0.34	0.77
Day 84	127.0	128.0	0.28	0.40
Day 112	130.0	129.0	0.42	0.59
Fat thickness[b], mm				
Initial	1.81	1.88	0.12	0.66
Day 56	3.60	3.68	0.13	0.67
Day 84	5.78	5.64	0.17	0.56
Day 112	8.27	8.53	0.19	0.32

[a] Supplement was formulated to contain no monensin or 33 ppm monensin.

[b] Fat thickness at the $12^{th}/13^{th}$ rib juncture determined using ultrasound.

Table 6. The effect of feeding monensin during a 56-day weight maintenance period on subsequent carcass yield and quality attributes

Trait	Supplement[a] fed prior to finishing period		SE	*P* =
	No Monensin	Monensin		
Pens	16	16		
Dressing percentage	61.04	61.32	0.27	0.48
Hot carcass wt. (HCW), kg	330	333	1.90	0.37
Fat thickness, mm	11.50	12.09	0.02	0.07
Longissimus area (LMA), cm^2	77.2	78.0	0.70	0.45
LMA/100 kg HCW	23.42	23.47	0.21	0.88
Internal fat (KPH), %	2.11	2.16	0.03	0.19
Yield grade	2.99	3.04	0.05	0.47
Maturity score[b]				
Skeletal	141	145	2.19	0.17
Lean	132	133	1.21	0.56
Overall	136	139	1.45	0.20
Marbling score[c]	409	420	9.24	0.41
Quality Grade				
Choice, %	56.46	55.63		
Select, %	42.29	40.00		
Standard, %	1.25	4.38		
Yield Grade				
1, %	4.38	1.25		
2, %	44.58	44.79		
3, %	48.96	48.96		
4, %	2.08	5.00		

[a] Supplement was formulated to contain no monensin or 33 ppm monensin.

[b] Maturity score: 100 to 199 = "A", between 9 and 30 months of age.

[c] Marbling score: 400 = "small[00]", the minimum required for U.S. Choice.

Table 7. Least squares means for rate and efficiency of gain, hip height, and fat accretion for steers following a 56-day period of limited feed intake prior to harvest and those not restricted

	Feed management[a]			
Trait	Ad libitum	Restricted	SE	*P* =
Pens	4	4		
Weight, kg				
Initial	292	292	--	--
Day 56	410	300	2.35	0.01
Day 84	449	338	4.23	0.01
Day 112	499	406	1.93	0.01
Day 140	558	475	2.72	0.01
Final	576	535	12.02	0.20
Daily gain, kg/d				
0 – 56	2.11	0.14	0.05	0.01
57 – 84	1.37	1.37	0.14	0.98
85 – 112	1.81	2.42	0.22	0.26
113 – 140	1.80	2.48	0.08	0.04
0 – Finish	1.70	1.33	0.05	0.04
Daily DM intake, kg/d				
0 – 56	7.87	3.42	0.19	0.01
57 – 84	8.82	5.65	0.28	0.02
85 – 112	9.38	8.48	0.13	0.06
112 – 140	10.16	11.09	0.30	0.22
0 – Finish	9.12	7.31	0.14	0.02

Gain:Feed, kg/kg				
0 – 56	0.264	0.020	0.011	0.01
57 – 84	0.165	0.249	0.021	0.15
85 – 112	0.194	0.285	0.019	0.12
112 – 140	0.177	0.223	0.008	0.09
0 – Finish	0.195	0.183	0.003	0.17
Calculated NEm, Mcal/kg	2.18	2.30	0.05	0.29
Calculated NEg, Mcal/kg	1.50	1.60	0.04	0.29
Hip height, cm				
Initial	118.0	117.2	1.89	0.84
Day 56	122.4	120.1	1.80	0.55
Day 112	126.9	124.4	1.43	0.43
Day 140	129.4	127.6	1.28	0.51
Final	130.1	130.6	3.27	0.94
Fat thickness[b], mm				
Day 56	5.57	2.05	0.15	0.01
Day 112	8.07	3.57	0.87	0.10
Day 140	8.91	5.93	0.40	0.05
Final	10.72	9.99	0.96	0.71

[a] Supplement was formulated to contain no monensin or 33 ppm monensin.

[b] Fat thickness at the $12^{th}/13^{th}$ rib juncture determined using ultrasound.

Table 8. The effect of a 56-day period of limited feed intake prior to harvest on carcass yield and quality attributes

Trait	Feed management[a]		SE	*P* =
	Ad libitum	Restricted		
Pens	4	4		
Dressing percentage	61.04	63.38	0.60	0.16
Hot carcass wt. (HCW), kg	352	339	8.06	0.34
Fat thickness, mm	13.46	12.70	0.09	0.75
Longissimus area (LMA), cm^2	79.53	79.53	1.08	0.99
LMA/100 kg HCW	22.59	23.60	0.43	0.34
Internal fat (KPH), %	2.21	2.14	0.25	0.88
Yield grade	3.27	3.08	0.02	0.04
Maturity score[b]				
Skeletal	156	148	13.78	0.77
Lean	134	135	4.13	0.93
Overall	145	141	8.26	0.82
Marbling score[c]	440	414	32.05	0.70
Quality Grade				
Choice, %	52.38	54.55		
Select, %	42.86	40.91		
Standard, %	4.76	4.55		
Yield Grade				
1, %	4.76	0.00		
2, %	38.10	36.36		
3, %	52.38	54.55		
4, %	4.76	9.09		

[a] Feed management: restricted steers were severely "limit fed" for the first 56 d afterwhich they were fed to achieve maximum gain; free choice steers were fed to achieve maximum gain beginning on d 1.

[b] Maturity score: 100 to 199 = "A", between 9 and 30 months of age.

[c] Marbling score: 400 = "small^{00}", the minimum required for U.S. Choice.

CHAPTER V

COMBINATION IMPLANTS: RESPONSE-LIFE AND EFFECTS ON PERFORMANCE, CARCASS CHARACTERISTICS, AND MEAT TENDERNESS

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ABSTRACT: To evaluate the response-life of a combination (120 mg TBA + 24 mg estradiol 17β; REV) anabolic implant, Angus x Senepol yearling steers (n = 100, 333 kg), that had received no prior implants, were assigned to one of five implant/explant regimes during a 140 d feeding trial. Treatments consisted of 1) no implant during the finishing period; 2) a single implant of REV on d zero; 3) as 2 but removal of that implant on d 56 and replacement with a second REV on d 56; 4) as 3 but removal and replacement on d 84, 5) as 3 but removal and replacement on d 112. Steers were given ad libitum access to a corn-based concentrate diet (2.12 Mcal/kg NEm and 1.36 Mcal/kg NEg). For the total trial, implanted steers, regardless of implant replacement regime, had greater (P < .05) daily gains (1.52 vs 1.05 kg/d), consumed more DM (9.01 vs 7.56 kg/d), and converted DM to live weight more efficiently than non-implanted cattle (0.169 vs 0.138 gain:feed). Implanted steers yielded heavier (P < .01) carcasses (334 vs 294 kg) that had more advanced (P < .01) skeletal maturity scores and larger

($P < .01$) *longissimus* areas. No differences ($P > .10$) in marbling score, percentage U.S. Choice (28.4 vs 41.7%), yield grade (3.3 vs 3.4), or Warner-Bratzler shear force measurements were detected among implanted vs non-implanted treatments. No differences ($P > .10$) in performance, carcass characteristics, or Warner-Bratzler shear force values were detected among single vs any of the multiple implant regimes. Implanted steers yielded carcasses that exhibited more advanced physiological maturity scores than carcasses from non-implanted steers. Because replacement of implants at any time prior to or at 112 d on feed did not improve performance, life span of these implants presumably exceeded 112 d. Previous reports of benefits from re-implanting on performance and detrimental effects of re-implanting on carcass quality may be due to total hormone concentration/load (stacking) rather than to exhaustion of hormonal delivery from previous implants.

Key Words: Beef, Implants, Feedlot, Performance, Carcass traits, Tenderness

Introduction

In the United States, growth-stimulating implants have been used commercially for over 30 years. Implants, containing natural or synthetic hormones, are used extensively in the beef industry because they enhance daily gain, feed efficiency, and often increase muscle mass of beef cattle. Based on an extensive literature review, Duckett et al. (1997) noted that implants improved ADG from 0 to 26% (mean 18%) and feed efficiency from 0 to 17% (mean 8%). Such improvements in feedlot performance indicate that if based solely on live performance, benefits from implants are substantial. However, when marketing

cattle on an individual value-based system (carcass basis), detrimental effects of implants on carcass quality and thus value have been detected. Specifically, implants may suppress the deposition of intramuscular fat (marbling; Duckett et al., 1996; Foutz et al., 1997) and advance skeletal maturity (Apple et al., 1991; Duckett et al., 1996; Foutz et al., 1997; Paisley et al., 1999). Consequently, implants may decrease carcass quality and value (Apple et al., 1991; Bartle et al., 1992; Foutz et al., 1997; Paisley et al., 1999).

Many feedlot cattle are re-implanted during the feeding period based on the assumption that implants expire, i.e., delivery of active ingredient(s) from the implant becomes sub-adequate to enhance performance. However, Duckett et al. (1996) reported that the benefits in terms of weight gain and gain:feed were drastically less for re-implants than for a single implant, even though marbling score and U.S. quality grade often were reduced by re-implants administered during the finishing phase.

Most research concerning the merits of re-implanting has consisted of ADDING a second implant, not REPLACEMENT of the first implant. Consequently, the value of a second implant could be due to the increased dosage achieved by addition of the second implant rather than inadequacy of the first implant. Expiration or response-life of the first implant can be evaluated directly through removing (explanting) the first implant when the second implant is given. The objectives of this study were to determine the response-life of a combination implant by testing performance responses to REPLACEMENT of that implant at various times. Effects of implant replacement on performance,

carcass characteristics, and Warner-Bratzler shear force measurements were measured.

Materials and Methods

Procedures in this research were routine livestock handling methods as outlined in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Consortium, 1988).

Animals and Diets

Spring born Angus x Senepol steers (n = 100) weighing 333 kg from a single herd and that had been born and raised as a group were received at the Oklahoma State progeny test facility in Stillwater, OK on June 13, 1998. These calves were source verified and had never received an implant in their lifetime prior to arrival at the test facility. Upon arrival, steers were weighed, stratified into four groups based on the percentage Senepol breeding (0, 25, 37.5, and 50%), and assigned randomly within breed type (blocks) to one of five implant/explant regimes. These five regimes consisted of: 1) no implant at any time during the finishing period (negative control); 2) a single implant of 120 mg TBA + 24 mg estradiol 17β (Revalor-S®, Hoechst Roussel Vet, Clinton, NJ) on d zero in the left ear; 3) an initial implant of Revalor-S® on d zero in the left ear, removal of that implant on d 56, followed by administration of a second Revalor-S® implant in the right ear on d 56; 4) an initial implant of Revalor-S® on d zero in the left ear, removal of that implant on d 84, followed by administration of a second Revalor-S® implant in the right ear on d 84; and 5) initial implant of Revalor-S® on d zero in the left ear, removal of that implant on d 112, followed by

administration of a second Revalor-S® implant in the right ear on d 112. Response to replacement of the original implant beyond that of steers implanted initially but not re-implanted was used as an index that the initial implant was not producing maximum performance. This differs from re-implant studies where the total implant dosage is increased by adding a new implant without removal of the previous implant.

Three days prior to receipt at the Oklahoma State progeny test facility, steers had been treated for internal and external parasite with doramectin (Dectomax®, Pfizer Animal Health, Exton, PA) and vaccinated with a modified live virus infectious bovine rhinotracheitis, bovine virus diarrhea, bovine respiratory syncytial virus, parainfluenza vaccine combination (BRSV Vac 4, Bayer Animal Health, Pittsburgh, PA). Steers were housed (5 steers/pen) in 20 partially covered 3.05 by 9.14 m pens (4 pens/block and 4 pens/treatment) with slatted floors and covered cement fence-line bunks and were provided with 2.95 m bunk space per steer. Cattle were re-treated for internal and external parasites with ivermectin (Ivomec®, Merial Limited, Iselin, NJ) pour-on on d 56 of the feeding period due to the presence of biting and sucking insects. A series of corn-based diets (Table 1) formulated to meet or exceed NRC (1996) nutrient requirements were fed twice daily at approximately 0700 and 1550 over a period of 18 d afterwhich steers were fed only the finishing ration for a total of 122 d. Steers were weighed immediately following transport to the feeding facility and at 28-d intervals thereafter. Feedlot daily gain was calculated from initial individual animal weights, considered to be shrunk weights, and final individual weights

(based on the assumption that fill was equal to 4% of full body weight). After 140 d on feed, steers were transported to and harvested at a commercial processing facility (Excel Corporation, Dodge City, KS).

Carcass Characteristics and Tenderness Assessment

Post-harvest, carcasses were chilled at 0°C for approximately 36-h, after which USDA quality and yield grade (USDA, 1997) carcass measurements were collected by University personnel. The *longissimus thoracis* (10th through 12th rib) lip-on (IMPS 112A; USDA, 1988), fabricated from the left side of each carcass, was vacuum packaged, and aged for five days at 2°C. Samples were then frozen for one hour prior to fabrication, after which three 2.54 cm thick steaks were obtained, vacuum packaged, and assigned to be aged at 2°C for a total of 7, 14, or 28 d postmortem. At the end of each assigned aging period, appropriate steaks were boxed, frozen again, and maintained at -40°C. Upon completion of the 28-d aging period, steaks were assigned randomly to one of six cook days. Twenty-four hours prior to cooking, appropriate vacuum packaged steaks were placed on metal trays, the vacuum was released, and steaks were tempered at 4°C (AMSA, 1995); no more than 10 steaks were removed from the tempering cooler prior to cooking. Steaks were broiled at 177°C in an impingement oven (Lincoln Impinger, Model 1022) to a final internal temperature of 70°C; temperatures were monitored with copper constantan thermocouples (Model OM-202, Omega Engineering, Inc., Stamford, Conn.). After steaks were cooled to 25°C, six to eight cores (1.27 cm diameter) were removed parallel to the longitudinal direction of the muscle fibers. Shear force values were obtained

for each steak by shearing each of the cores once using a Warner-Bratzler attachment to an Instron Universal Testing Machine (Model #4502, Instron, Canton, MS) moving at a crosshead speed of 200 mm/min. The peak force (kg) was recorded by an IBM PS2 (Model 55 SX) using software provided by Instron Corporation; the mean peak force for the cores was analyzed as an objective measurement of tenderness.

Statistical Analysis

Data were analyzed as a randomized block design using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with implant time being the class variable and percentage Senepol serving as a blocking factor; pen served as the experimental unit. Live weight, feed consumption, carcass data, and meat tenderness differences were analyzed using pen as the experimental unit. Although additional differences were detected when animal was used as the experimental unit for statistical analysis, data trends were similar to those observed based on pen means; thus, all data reported are based on pen means. Treatment sums of squares were separated using non-orthogonal contrasts that compared: 1) control vs the average of all implanted steers (CI); 2) response to a second implant following explant of first implant on d 56 vs steers implanted on d 0 but not re-implanted (D56); 3) response to a second implant following explant of first implant on d 84 vs steers implanted on d 0 but not re-implanted (D84): 4) response to a second implant following explant of first implant on d 112 vs steers implanted on d 0 but not re-implanted (D112).

Results and Discussion

Mean, minimum, and maximum pen values for selected live performance and carcass characteristics are presented in Table 2. Mean initial live weight for the steers was 333 kg and mean final shrunk live weight was 533 kg for a mean daily gain of 1.43 kg. Daily dry matter consumption averaged 8.72 kg, which resulted in 0.16 kg of cattle gain for each kg of feed consumed. Dressing percentages for individual pens ranged from 57 to 65% and averaged 61.1%; values tended to be lower than the industry average, probably due to large rumen fill associated with feeding a whole corn-based diet. Mean adjusted fat thickness averaged 15.20 mm and *longissimus* area averaged 78.68 cm^2 which resulted in a mean yield grade of 3.32. Marbling score ranged from traces to moderate with mean marbling score being 81 percentage points into the slight marbling category. Warner-Bratzler shear force values ranged from 2.66 to 7.16 kg and yielded a mean of 4.10 kg after 7 d postmortem aging.

Live Animal Performance

Performance data are reported in Table 3. Steers that were implanted, regardless of explant regimen, had greater ($P < .05$) daily weight gains than non-implanted steers during the 140 d finishing period; overall, implanting enhanced daily gain by 45%. Performance advantages of this magnitude from implants are rare. Duckett et al. (1997) summarized that the expected ADG response to a single estrogen plus TBA implant was 26%, while Bartle et al. (1992) and Johnson et al. (1996) both concluded that the daily gain advantage for steers receiving estrogen combined with TBA was more than 15%. The 45%

improvement in daily weight gain observed in the present trial resulted in 13.6% (65.3 kg) greater ($P < .05$) final live weights and 13.4% (39.5 kg) more ($P < .05$) kg carcass weight for implanted steers vs their non-implanted counterparts. The increased DM intake for implanted vs non-implanted steers is suggested to be responsible for a portion of the added gain observed for implanted cattle (Duckett et al., 1996). Steers that were implanted in this study consumed 19% more ($P < .05$) feed and required 18% less ($P < .05$) feed per kg of live weight gain than non-implanted controls (0.169 vs 0.138 kg gain/kg DM). Although substantially greater, these data support the overall conclusion that implanting increases DM intake (13%, Duckett et al., 1996) and reduces DM required per kg weight gain (13%, Johnson et al., 1996; 10%, Duckett et al., 1996). In contrast with many implant trials, the implant history of the steers used in this study was known; we were certain that these cattle had never received any implants earlier in their life. Carryover from previous implants may influence mature size and thereby the performance benefits from implants.

No differences ($P > .10$) in daily gain or DM consumption attributable to any of the explant/implant regimes were detected. These data contrast with means reported by Duckett et al. (1997) that re-implanting enhanced daily gain (25%) and gain:feed (8%) when compared with non-implanted steers. Although not compared directly, extrapolation of the data reported by Duckett et al. (1997) revealed that a second implant did not enhance gain (1.44 vs 1.47 kg/d) even though a second implant resulted in a 6.5% improvement in gain:feed compared with steers that had received a single implant. Results support the data of Foutz

et al. (1997) which indicated DM intake was not affected by a second implant. In the review of implant effects on performance, Duckett et al. (1996) also suggested that a second implant (re-implant) did not consistently enhance gain:feed (25 of 85 trials). Because response to a second implant was not (P > .01) detected in our study, these data may be interpreted to suggest that the quantity of hormone released from a single implant of the type tested, when administered only once at the onset of the finishing period, provides and maintains sufficient hormone concentrations needed to provide maximum implant response during a 140 d finishing period. However, these data should not be interpreted to indicate that re-implanting cannot elicit additional performance benefits. Indeed, re-implanting steers may enhance performance if there is some benefit from the additional hormonal load provided, i.e., "hormone stacking," if the supply of hormone provided by the first implant was not adequate to maximize performance for the full feeding period. In support of this concept, Duckett et al. (1997) reported that the greatest improvements in gain:feed were observed when an estrogenic implant was followed by a more potent implant (estrogen plus trenbolone acetate).

Carcass Traits

Carcass measurements are reported in Table 4. Dressing percentage was not (P > .10) altered by the use or frequency of implanting as previously concluded by Hutcheson et al. (1993), Duckett et al. (1996), and Foutz et al. (1997). However, because of heavier final live weights, implanted steers yielded 39.5 kg (13.4%) heavier (P < .05) carcass weights than the non-implanted steers.

Foutz et al. (1997) concluded that the use of estrogen plus TBA enhanced carcass weight by 7 kg (2.1%), while Duckett et al. (1996) concluded carcasses from implanted steers were 5.5% (16.9 kg) heavier than their non-implanted counterparts. No differences ($P > .10$) in external fat thickness, percentage internal fat, or *longissimus* muscle area per unit of carcass weight were detected; thus, mean yield grade was comparable among all carcasses regardless of implant regimen, similar to responses reported by both Duckett et al. (1996) and Foutz et al. (1997). Although carcasses from steers that received an implant had larger ($P < .05$) *longissimus* areas, this difference can be ascribed at least partly to the heavier carcass weights of the implanted steers; implants did not ($P > .10$) increase *longissimus* area per kg carcass weight.

Lean maturity scores were similar ($P > .10$) among all implant treatment groups, but carcasses from implanted steers consistently had more ($P < .05$) advanced skeletal maturity scores (mean of 28-degrees) than carcasses from non-implanted steers. Consequently, overall maturity scores were 13 degrees farther ($P < .05$) into the "A" maturity group for carcasses from implanted steers. Despite accelerating maturation, all carcasses remained well within the "A" maturity classification; however, these data support the concept that the maturity score, and thereby the quality grade of those cattle producing carcasses near the "A" - "B" maturity "break point," might be affected adversely by implanting. If historical carcass data indicate that steers/heifers from a given source or background may produce "B" maturity carcasses, then implants may exclude such cattle from the U.S. Choice and U.S. Select quality grades (USDA, 1997).

Duckett et al. (1996, 1997) also summarized that skeletal and overall maturity scores were more youthful for cattle that had received a single implant containing zeranol or trenbolone acetate (TBA) as compared with those administered multiple implants, of which at least a portion was estrogen. Foutz et al. (1997) reported that skeletal maturity was more advanced among steers that received estrogen or estrogen in combination with TBA vs trenbolone acetate alone or no implant, but TBA implants alone did not accelerate calcification of cartilage. Apple et al. (1991) reported that non-implanted steers and steers administered a single trenbolone acetate implant had more youthful skeletal maturity scores than steers implanted with any of the estrogen-like or estrogen-containing anabolic substances, except for steers implanted with zeranol. Carcasses from steers that received a single zeranol implant had similar skeletal maturity scores to both the control and TBA steers even though steers were harvested at similar chronological ages; carcasses from TBA treated steers had younger skeletal maturity scores than groups that had received estrogen-containing implants. The data of Apple et al. (1991) can be summarized to indicate that combination implants containing estrogen may result in more advanced skeletal and overall maturity indices than implants containing only TBA.

Although the difference was not significant ($P > .10$), carcasses from implanted steers tended to have reduced marbling scores. Consequently, the percentage of U.S. Choice carcasses (premium Choice plus low Choice) tended to be lower and the frequency of U.S. Select carcasses tended to be higher. Similarly, Duckett et al. (1996) concluded that 14.5% fewer cattle qualified for the

U.S. Choice quality grade if they had previously received an implant during the finishing phase (74% for non-implanted vs 59.5% for implanted steers).

Longissimus Properties

Values for shear force and percentage of steaks that, based on taste panel evaluation, might have been classified as tender (< 3.84 kg shear force) and tough (> 4.5 kg shear force) are presented in Table 5. No effect ($P > .10$) of implant regimen on shear force values for steaks aged 7, 14, or 28 d was detected, but numerically at 7 d postmortem, steaks from non-implanted steers required 0.35 kg (8.4%) less ($P > .10$) force to shear than steaks from implanted steers. Fewer steaks from implanted steers had shear force values less than 3.84 kg and more steaks had values greater than 4.5 kg (Table 5). Similar effects of implants on WBS measurements were reported by Duckett et al. (1996) and Foutz et al. (1997); WBS values were increased by 0.27 and 0.32 kg, respectively, as a result of implanting.

Implications

Implanting feedlot steers with a combination (estrogen plus trenbolone acetate) implant enhanced rate and efficiency of gain. However, replacement of implants at up to 112 d during the 140-d finishing period did not improve performance. This suggests that life span of the implant used in the present study (120 mg TBA + 24 mg estradiol 17β) must have exceeded 112 d. Perhaps the performance responses often noted following re-implanting is due to hormone stacking, not to exhaustion of previous implants. Implants had negative effects on carcass quality (decreased marbling score plus accelerated carcass maturity

indices). These detrimental effects of implants on carcass quality and value must be balanced against the benefits in daily gain and feed efficiency from implanting to judge the economic merit of specific implant schemes.

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Table 1. Composition of diet (DM basis) fed to steers during a 140-day finishing period

	Percentage concentrate			
Ingredient, %	60	70	80	Final
Corn grain, whole shelled	51.59	61.59	71.59	86.53
Alfalfa, dehydrated	20.00	15.00	10.00	--
Cottonseed hulls	20.00	15.00	10.00	5.09
Supplement [a]	8.41	8.41	8.41	8.41

---------- Calculated Analysis (NRC, 1996) ----------

Nutrient	Final Diet Composition, DM basis
NEm, Mcal/cwt	2.12
NEg, Mcal/cwt	1.36
Crude protein, %	11.88
Crude fiber, %	5.13
Potassium, %	0.67
Calcium, %	0.48
Phosphorus, %	0.33

[a] Supplement composition: 44% CP cottonseed meal, 5.09%; limestone, 1.13%; NPN, 0.45%; trace mineralized salt, 0.33%; potassium chloride, 0.34%; Rumensin®-80, 0.02%; Tylan®-40, 0.011%; Vitamin A-30,000 IU/g, 0.011%; selenium-600, 0.006%; manganous oxide, 0.005%; zinc sulfate, 0.003%; copper sulfate, 0.001%.

Table 2. Live, carcass, and meat attributes for steers evaluated to determine response-life of a combination implant

Trait	Mean	Minimum	Maximum	SD
Initial weight, kg	333	324	349	5.80
Final weight, kg	533	464	572	31.07
ADG, kg/day	1.43	0.88	1.75	0.23
Daily DM intake, kg/day	8.72	6.80	11.14	1.01
Gain:Feed, kg/kg	0.16	0.12	0.20	.02
Dressing percentage	61.11	57.21	64.52	1.50
Hot carcass wt. (HCW), kg	326	254	392	29.55
Fat thickness, mm	15.2	1.16	1.80	0.13
Longissimus area (LMA), cm^2	78.69	55.48	94.82	8.32
LMA/100 kg HCW	24.12	21.46	25.73	1.02
Internal fat (KPH), %	2.47	1.50	4.00	0.62
Yield Grade	3.32	2.11	4.49	0.47
Maturity score[a]				
Skeletal	143	110	180	17.47
Lean	149	120	180	11.44
Overall	146	125	180	10.59
Marbling score[b]	381	280	600	57.89
Shear Force, kg				
Day 7	4.10	2.66	7.16	0.93
Day 14	3.49	2.02	5.92	0.62
Day 28	2.98	2.29	4.68	0.46

[a] Maturity score: 100 to 199 = "A", between 9 and 30 months of age.

[b] Marbling score: 600 = "moderate^{00}", the minimum required for U.S. High Choice; 300 = "slight^{00}", the minimum required for U.S. Select; 233 = "traces^{33}", the minimum required for U.S. High Standard.

Table 3. Least squares means for rate and efficiency of gain of steers fed during a 140-day finishing period

Item	Implant regimen[a]					SE	Effect[b]
	Control	R0	R56	R84	R112		
Pens (steers)	4 (20)	4 (20)	4 (20)	4 (20)	4 (20)	--	--
Weight, kg							
Initial	334	331	333	333	336	2.96	--
Final[c]	481	546	547	547	545	7.05	CI
Carcass adj.[d]	481	545	544	547	548	7.29	CI
Daily gain[e], kg/d							
0 – 28	1.15	2.03	1.97	2.02	1.97	0.19	CI
28 – 56	1.08	1.49	1.52	1.17	1.49	0.12	ci
56 – 84	0.68	1.16	1.41	1.51	1.32	0.20	ci
84 – 112	1.37	1.40	0.96	1.33	1.00	0.17	--
112 – 140	0.96	16.61	1.79	1.62	1.71	0.16	CI
Total	1.05	1.54	1.53	1.53	1.50	0.05	CI
Carcass adj.	1.05	1.53	1.51	1.52	1.52	0.05	CI
Feed intake, kg/d							
0 – 28	7.39	8.53	7.98	9.03	8.21	0.57	--
28 – 56	7.21	9.21	8.98	8.75	9.03	0.56	ci
56 – 84	7.08	8.71	9.07	8.94	9.48	0.43	ci
84 – 112	7.30	9.21	7.94	8.30	8.26	0.57	--
112 – 140	8.85	11.07	9.66	10.34	9.66	0.54	--
Total	7.58	9.34	8.71	9.07	8.94	0.35	CI

Gain:Feed							
0 – 28	0.144	0.236	0.244	0.220	0.236	0.014	CI
28 – 56	0.149	0.159	0.160	0.120	0.161	0.018	--
56 – 84	0.092	0.125	0.152	0.145	0.137	0.019	CI
84 – 112	0.182	0.146	0.115	0.156	0.120	0.015	ci
112 – 140	0.099	0.142	0.182	0.157	0.174	0.016	CI
Total	0.138	0.165	0.175	0.168	0.168	0.006	CI
Carcass adj.	0.144	0.236	0.244	0.220	0.236	0.005	CI
Diet NEm, Mcal/kg DM	1.86	1.95	2.06	1.99	2.00	0.05	--
Diet NEg, Mcal/kg DM	1.25	1.31	1.40	1.34	1.35	0.05	--

[a] Implant regimen: Control = never implanted; R0 = a single implant of Revalor-S® on day zero; R56 = initial implant of Revalor-S® on day zero, removal on day 56 and a second Revalor-S®; R84 = Revalor-S® on day zero, removal on day 84, second Revalor-S®; R112 = Revalor-S® on day zero, removal on day 112, second Revalor-S®.

[b] Effect:
CI = Control vs all implanted steers ($P < .05$); ci = Control vs all implanted steers ($P < .10$).

[c] Final weight = gross weight*0.96.

[d] Carcass adjusted gain = carcass weight ÷ .6111.

[e] ADG was calculated after a 4% pencil shrink was applied to all full weights.

Table 4. Least squares means for carcass traits of steers with different implant regimens and fed for 140 days

Item	Implant regimen[a]					SE	Effect[b]
	Control	R0	R56	R84	R112		
Pens (steers)	4 (20)	4 (20)	4 (20)	4 (20)	4 (20)	--	--
Dressing percentage	61.1	61.0	60.8	61.0	61.5	0.43	--
Hot carcass wt. (HCW), kg	294	333	332	334	335	4.45	CI
Fat thickness, cm	1.42	1.60	1.52	1.52	1.60	0.06	--
Longissimus area, cm^2	71.60	79.98	81.27	78.05	81.92	3.84	CI
Longissimus area/100 kg HCW	24.35	24.02	24.48	23.37	24.45	0.45	--
Internal fat (KPH), %	2.83	2.36	2.40	2.41	2.38	0.30	--
Yield Grade	3.38	3.36	3.22	3.39	3.29	0.24	CI
Maturity score[c]							
Lean	151	144	147	153	149	5.69	--
Skeletal	120	150	148	148	146	6.77	CI
Overall	135	147	147	150	148	4.65	CI
Marbling score[d]	396	374	387	361	387	13.24	--
Quality Grade							
Premium Choice, %	13.3	0.0	5.0	0.0	10.0	5.16	
Choice, %	28.3	21.3	30.0	22.5	25.0	11.92	
Select, %	58.3	78.8	60.0	72.5	65.0	15.81	
Standard, %	0.0	0.0	5.0	5.0	0.0	3.29	
Yield Grade							
2, %	15.0	10.0	25.0	25.0	30.0	9.35	
3, %	66.7	72.5	75.0	57.5	70.0	10.64	
4, %	18.3	17.5	0.0	17.5	0.0	8.77	

[a] Implant regimen: Control = never implanted; R0 = a single implant of Revalor-S® on day zero; R56 = initial implant of Revalor-S® on day zero, removal on day 56 and a second Revalor-S®; R84 = Revalor-S® on day zero, removal on day 84, second Revalor-S®; R112 = Revalor-S® on day zero, removal on day 112, second Revalor-S®.

[b] Effect:
CI = Control vs all implanted steers ($P < .05$);

[c] Maturity score: 100 to 199 = "A", between 9 and 30 months of age.

[d] Marbling score: 400 = "small^{00}", the minimum required for U.S. Choice.

Table 5. Least squares Warner-Bratzler shear force means of *longissimus* steaks from steers with different implant regimens and fed for 140 days

	Implant regimen[a]						
Item	Control	R0	R56	R84	R112	SE	Effect[b]
Pens (steaks)	4 (20)	4 (20)	4 (20)	4 (20)	4 (20)	--	--
Shear force, kg							
7 day	3.82	4.11	4.28	4.26	4.03	0.20	--
14 day	3.42	3.43	3.54	3.50	3.54	0.09	--
28 day	2.94	3.15	2.95	2.94	2.98	0.11	--
< 3.84 kg, %							
7 day	76.7	62.5	55.0	37.5	45.0		
14 day	76.7	73.8	80.0	75.0	75.0		
21 day	71.7	95.0	95.0	95.0	90.0		
> 4.5 kg, %							
7 day	13.3	20.0	30.0	31.25	25.0		
14 day	5.0	0.0	10.0	0.0	0.0		
21 day	0.0	5.0	0.0	5.0	0.0		

[a] Implant regimen: Control = never implanted; R0 = a single implant of Revalor-S® on day zero; R56 = initial implant of Revalor-S® on day zero, removal on day 56 and a second Revalor-S®; R84 = Revalor-S® on day zero, removal on day 84, second Revalor-S®; R112 = Revalor-S® on day zero, removal on day 112, second Revalor-S®.

[b] Effect:
Implant regimen did not ($P > .10$) affect mean shear force values on a pen mean basis.

VITA

Brett A. Gardner

Candidate for the Degree of

Doctor of Philosophy

Thesis: EFFECTS OF IMPLANTS AND MONENSIN ON BODY WEIGHT MAINTENANCE, FEEDLOT PERFORMANCE, AND CARCASS CHARACTERISTICS

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