EFFECTS OF COMBINATION ANDROGENIC AND ESTROGENIC ANABOLIC IMPLANTS ON BOXED BEEF YIELDS OF SERIALLY-SLAUGHTERED STEERS

By

MOHAMMED TAHA AL-MAAMARI

Bachelor of Food Science
Riyadh, Saudi Arabia
1985

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1993

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Thesis Approved:

Thesis Adviser

Dean of the Graduate College

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Format of Dissertation

This dissertation is presented in the Journal of Animal Science style and format, as outlined by the Oklahoma State University graduate college style manual. The use of this format allows for independent chapters to be prepared suitable for submission to scientific journals.

CHAPTER I

INTRODUCTION

Of the many challenges that the cattle industry must address, none is more fundamental than improving the efficiency of animal production. An unfavorable lean-to-fat ratio is a major problem in beef cattle, sheep, and swine carcasses. For beef to remain competitive in the retail case, it is essential to provide an environment which maximizes the animal's ability to grow and to convert feedstuffs into highly palatable, nutritious meat. Today's price-conscious consumer has dictated that the beef industry must renew its commitment to produce beef efficiently. Although consumer demographics suggest that health and palatability concerns are valid issues, the single largest liability of the beef industry is inefficiency of production. In the U.S. beef industry, over 3 billion pounds of excess fat are trimmed each year (Allen et al., 1976). In addition, Smith et al. (1991) estimated that $279.82 was lost per head due to inefficiency of production; this value was reduced by $3.23 to $276.59 in 1995 (Smith et al., 1995). Ultimately passed on to the consumer, these costs have reduced beef's market share. The primary methods to improve beef quality according to by the 1991 National Beef Quality Audit were to reduce excessive external fat, decrease excessive seam fat, improve overall cutability and increase the understanding about the value of closely-trimmed products. Research efforts to

improve the market position of beef have focused on specific production and management schemes that may result in a leaner carcass.

Cattle of larger mature size have greater lean tissue yield. However, this approach has several disadvantages. Large mature size cattle and stocker animals may not fit some production systems. Moreover, size restrictions in the weight of boxed beef place a limit carcass weight and cattle size (Morgan et al., 1995). Additionally, extremely heavy weight carcasses may pose a safety problem for workers through exceeding the maximum tolerance of equipment, vacuum bags, and boxes (Dolezal, 1995).

Lowering the plane of nutrition may reduce the amount of fat in a carcass while maintaining rate of weight gain and increasing rate of protein gain. However, a low grain diets that will reduce rate of growth result in poorer feed efficiency and greater cost of gain; they also have negative effects on palatability, flavor and color of steaks. Use of intact males or bullocks provides another opportunity for enhancing lean beef production. Bulls grow more rapidly, utilize feed more efficiently and produce a higher-yielding carcass with less fat and more edible product. However, bulls are aggressive and their carcasses have low quality grades and are discounted into the USDA grade for bullocks (Field, 1971, Seidemen et al., 1982). Trimming fat from the carcass is practiced today to fabricate leaner beef, but trimming costs labor and the trimmed fat poses additional handling and marketing problems. Although greater fat deposition often is associated with enhanced meat quality, fat deposition is extremely inefficient in terms of production of edible product.

Although each of these methods separately or in combination can add flexibility to the process of producing leaner beef, none has greater potential for growth regulation than growth-promoting hormones. Growth promotants include

anabolic (growth-enhancing) substances that function in a manner physiologically similar to sex steroids to increase nitrogen retention and protein deposition by the animal (Heitzman, 1979). The hormones in growth promotant implants often are classified as repartitioning agents. These are defined as "substances that can direct absorbed nutrients to increase skeletal muscle deposition and decrease fat deposition with the end goal of increasing average daily gain and improving feed efficiency at equal levels of nutrient intake" (Rains, 1992; Preston and Hershler, 1992). Anabolic agents are classified regarding their metabolic effect (estrogenic or progestogenic), whether they are biologically endogenous or exogenous, and whether they are steroids or non-steroidal (Patterson and Salter, 1985). Approximately 90% of the cattle in the United States are implanted in commercial feedlots, this value approaches 100% (NCA, 1994). Hormone implants have been used extensively in beef production for almost 4 decades. Although estrogenic implants have been the primary form marketed in the U.S. the androgenic steroid trenbolone acetate (TBA), a potent synthetic analog of testosterone, has been gaining acceptance since it was approved for use in meat animals. This synthetic androgen acts in concert with estrogen. TBA plus estrogen improves growth rate and feed efficiency substantially more than either implant alone (Trenkle, 1985; Anderson et al., 1992a 1992b, and Bartle et al., 1992). The combination typically shifts both performance and carcass traits more dramatically than estrogenic compounds alone (Belk, 1992). However, anabolic implants usually lower marbling scores and reduce the percentage of cattle grading U.S. Choice (Prior et al., 1978; Owens et al., 1980; Turner et al. 1981; Foutz et al., 1989a; 1989b, Belk, 1992; Hardt et al., 1995; and Mader (1994). Effect of this combination on carcass quality and yield grades has not been examined thoroughly and results often

have been conflicting. For example, Foutz et al. (1989c) indicated that TBA had a slight effect on quality grade; Mader (1994) detected no effect. Further, most research has examined feedlot performance, not carcass characteristics; few studies have investigated the effects on carcass quality and yield grade at similar slaughter weights. No data are available concerning the effect of estrogenic and androgenic implants on closely-trimmed boxed beef yields.

The objective of this study was to determine the effect of estrogenic and (or) androgenic implants administered at the start of the finishing phase and (or) at reimplant time on carcass grade traits and yield of boxed beef and subprimal cuts.

CHAPTER II

GENERAL REVIEW OF LITERATURE

Factors Altering Growth and Body Composition

Hormones Involved in Growth.

Growth regulation affects many aspects of animal physiology. Hormones play both primary and permissive roles in the timing and progression of growth in total body size and in mass of individual tissues (Galbraith and Topps, 1981). Knowledge about growth regulation as permited humans to alter on growth and development of livestock. The endocrine control of growth (defined as skeletal growth and protein accretion, i.e., the difference between synthesis and degradation) involves several hormones which control the interplay among nutrient supply, genetic potential and the environment. Although these interactions are not fully defined, growth hormone (GH) appears essential for the normal growth of young animals. The myriad of metabolic functions involved in growth is beyond the scope of this review; therefore this discussion will be restricted to the direct impact of hormones on animal growth. Classically, there are six hormones or groups of hormones involved in growth - growth hormone, thyroid hormone(s), insulin, glucocorticoids, androgens, and estrogens.

Growth Hormone (GH).

Growth hormone, also called *somatotropin,* is the most widely studied hormone which exerts a large affect on growth. Growth hormone, an anabolic agent that directs absorbed nutrients toward skeletal muscle deposition and away from fat deposition, increases average daily gain and improves feed efficiency (Bauman, 1982; Buttery and Sinnet-Smith, 1984). Although exactly why GH increases protein deposition is not known, several mechanisms may be involved. These include an enhanced amino acid transport through the cell membrane (Trenkle, 1974), enhanced RNA translation to promote synthesis by the ribosomes, increased nuclear transcription of DNA from RNA, and decreased catabolism of protein and amino acids. Mosely et al. (1982) reported that bovine GH treatment increased nitrogen retention by steers. Likewise, steers implanted with estradiol 17-β usually have greater nitrogen retention (Cecava and Hancock, 1994). GH concentration has been related positively to carcass muscle and RNA in muscle but negatively to carcass fatness of cattle (Trenkle and Topple, 1978). Similar effects have been reported for lambs (Wagner et al., 1978) and swine. Treatment of pigs with GH enhances growth rate, improves feed efficiency and increases leanness (Michelin, 1972; Chung et al., 1986; Campbell et al., 1989; Kanis et al., 1990).

One of the primary actions of GH is to enhance formation of insulin-like growth factors (IGF). Formally called *somatomedins,* IGF are found in the liver (Spencer, 1985) and peripheral tissues (Jeffcoatel, 1993). *Somatomedins* include a family of circulating polypeptides produced by several different body tissues. IGF presumably coordinates activity of GH. The hypothalamus releases GH releasing hormone (GHRH) which stimulates

the anterior pituitary to release GH. GH then travels to receptors in the liver where IGF-I is secreted. IGF-I also may act in an autocrine fashion, being produced in bone, muscle, adipose, and other tissues to enhance GH effects. Both GH and IGF-I increase protein anabolism and fat catabolism (Michelin, 1972; Galbraith and Topps, 1981).

Insulin.

Insulin is the anabolic hormone which controls the metabolism of all the major energy sources, including carbohydrate, fat, and protein. High insulin concentrations favor anabolism and storage of energy. It enhances synthesis and deposition of glycogen in liver, synthesis of fatty acids by liver and adipose tissue, deposition and retention of triglycerides by adipose tissue, and uptake of amino acids and incorporation of amino acids into protein of muscle and other tissues. Insulin is required for glucose entry into most cells where glucose is metabolized. An excess of insulin reduces blood glucose concentrations. A deficiency of insulin, through reducing uptake of glucose by cells, causes glucose concentration to increase extracellularly, i.e., in blood, even though cells are starved for glucose. Plasma insulin concentration is correlated positively with carcass adiposity and negatively with carcass muscularity (Trenkle and Topple, 1978). However, insulin also plays a major role in protein synthesis by inhibiting protein degradation and by promoting amino acid deposition in tissue protein (Prior and Smith, 1983). How insulin increases protein storage is not understood as well as its action on glucose and fat storage. Apparently, insulin probably plays a secondary or supportive role rather than being directly involved in protein growth, possibly through

enhancing somatomedin secretion. Involved with active transport of many amino acids into cells, insulin increases translation of messenger RNA, increases the rate of transcription of selected DNA, inhibits the catabolism of protein, and depresses the rate of gluconeogenesis. (Prior et al., 1983; Guyton, 1991).

Thyroid Hormone.

Thyroid hormone regulates metabolism of most organs and is considered essential for growth. Thyroid hormone causes nuclear transcription to large numbers of genes (Guyton, 1991). Consequently, all cells of the body, a great number of protein enzymes, structural proteins, transport protein, and other substances require thyroid hormone (Guyton, 1991). More specific functions of thyroid hormone during tissue growth include an increase in cellular metabolic activity, an increase in the number and size of the mitochondria, and an increase in active transport of ions through membranes. Thyroid hormone stimulates carbohydrate metabolism, enhances fat catabolism, and decreases the concentrations of cholesterol, phospholipids and triglycerides in blood plasma (Guyton 1991). When thyroprotein, a thyroxin precursor, was administrated to heifers at a level of 0.5 g / 100 lb. body weight, live weight gain was decreased by 8% (Dinusson et al. 1950). Ely et al. (1976) similarly found that thyroprotein decreased gain in lambs. Although thyroprotein suppresses fat deposition, when combined with GH, thyroprotein increases protein deposition (Wagner and Veenhuzen, 1978). More importantly, thyroid hormone plays a dual role, stimulating both synthesis and breakdown of protein, thereby increasing muscle turnover.

Overall effects on protein accretion are dose dependent. High doses of thyroid hormone have catabolic effects whereas low doses may stimulate growth. Implanting steers with Synovex-S® increased thyroid concentrations slightly (Rumsey et al., 1992).

Glucocorticoids.

Glucocorticoids are hormones secreted by the adrenal cortex. They are named for their effect of increasing the concentration of glucose in blood. The two best-known metabolic effects of glucocorticoids are their stimulation of gluconeogenesis (the formation of carbohydrate from proteins and other substances) by the liver and mobilization of amino acids from tissue. However, glucocorticoids have additional effects on both protein and fat through their effect on carbohydrate metabolism. Glucocorticoids reduce protein reserves in all cell bodies while increasing liver proteins and plasma protein. Thus, such hormones are considered to be growth inhibiting steroids (Spencer, 1985; Sharpe et al., 1986). In contrast, androgenic steroids suppress the adrenal gland's production of glucocorticoids (Isaacson et al., 1991).

Aspects of Anabolic Implants and Cattle Growth

Even though anabolic agents have been used in animal production since the 1930's (Galbraith and Topps, 1981), only since the 1950's have the present generation of anabolic implants which contain natural anabolic estrogens been used in beef cattle production. Synovex-S® implants containing estradiol, and Ralgro® implants containing zeranol, were cleared

for use in the United States in 1955 and 1969, respectively. However, only recently was trenbolone acetate (TBA), an androgenic synthetic analog of testosterone, approved for use in meat animals. Despite subsequent clearance of other anabolic implants, just three, i.e., Ralgro®, Synovex-S® and Revalor-S®, are the major implants used in beef cattle. Relationships of commercial implants to various endogenous sex steroids, their mode of action and their effect on carcass merit will be reviewed next.

Relationships of Commercial Implants to Endogenous Sex Steroids.

Growth promoting hormones that are approved for use in the United States generally are compounds that either occur naturally in the animal's body, i.e., the endogenous sex hormones - estrogen, testosterone or progesterone, or synthetic analogs of these natural compounds. The justification for using such hormones is to compensate or augment hormones in the animals' body which are decreased below normal levels as a result of castration (Roche, 1983). Manufacturing, marketing, and use of hormone implants in the United States is regulated by the Food and Drug Administration. Exogenous hormones typically are impregnated in silastic rubber or compressed into pellets based on lactose or cholesterol to form an implantable mass (Istasse et al., 1988). Implants are administered subdermally in the back of the ear of cattle; the hormone is gradually released from the implant into the blood stream of the animal. To date, five products are approved for use in the United States; three of these are naturally occurring hormone products and two are synthetic (NCA, 1995). Synovex-S® (20 mg estradiol benzoate plus 200 mg progesterone) and Synovex-H®, (20

mg estradiol benzoate + 200 mg testosterone propionate) are approved for enhancing growth rate of steers and heifers (Botts et al., 1986). Steer-Oid® and Heifer-Oid® contain the same active compounds as Synovex-S® and Synovex-H®. Compudose-200®, an estrogenic implant, contains estradiol 17-β as the active compound (Mathison and Stobbs, 1983). Ralgro®, an anabolic agent that enhances the retention of nitrogen, contains resorcyclic acid or zeranol, a plant estrogen isolated from the mold *Giberella zea* (Fisher et al., 1986). The androgenic implant, Finaplix® is used to improve feed efficiency in growing finishing feedlot steers. The anabolic agent in this implant, trenbolone acetate, is a synthetic analog of testosterone thought to be 8 to 10 times more active than testosterone (Rico and Sacaze, 1984; Trenkle, 1987; Anderson, 1991). Melengestrol acetate (MGA) is a progestogenic anabolic compound which is administered orally to suppress estrus (Patterson et al., 1989). Several studies have found that MGA improves feedlot performance of heifers. MGA prevents fluctuations in concentrations of estrogen in intact cycling heifers by blocking the release of luteinizing hormone; thereby, follicles do not ovulate but continue to produce estrogen (Hutcheson et al., 1993).

With the exception of zeranol, all of the commercial compounds and parent hormones have the same basic 17 carbon and four ring structure characteristics of cholesterol. Differences in biological activity among these endogenous steroids have been attributed to differences in either the number and (or) location of the double bounds in the rings or the groups attached to the 10, 13, or 17 carbons. Botts et al. (1986) indicated that estradiol benzoate, MGA and testosterone propionate, though not identical in structure to their endogenous parent compound, are considered to be natural because

they are converted readily into the endogenous form of the hormone and are metabolized similarly. In contrast, zeranol and trenbolone acetate (TBA) exhibit activities similar to their respective parent compounds but are not readily metabolized into the endogenous forms of estrogen and testosterone; thus, they are classified as xenobiotics (synthetic hormones).

Mode of Action for Anabolic Compounds

Anabolic implant hormones presumably stimulate growth by increasing nitrogen retention by muscle. They repartition nutrients, increasing the nutrient storage in and growth of the more desirable higher-valued components (muscle) and decrease the nutrient flux to less desirable components of the carcass (fat); thereby, they increase the percentage of lean tissue (Belk, 1992). Depending on their mode of action, anabolic growth hormones are classified as either estrogenic or androgenic.

Probable Mode of Action for Estrogens.

The mechanism by which estradiol and zeranol exert their anabolic effects has been reviewed by Buttery et al. (1978), Trenkle (1983), Johnson et al. (1984), and Cross and Belk (1989). Most research on the mode of action of anabolic agents has focused on factors regulating protein deposition. Although the precise mode of action is unclear, two possible mechanisms for increasing protein accretion have been suggested. First, estrogens may act directly at the muscle cell and regulate protein synthesis and degradation (Heitzman, 1979); secondly, they may act indirectly through modifying endocrine activity (Trenkle, 1983). Katzenellenbogen et al. (1979) reported

that zeranol interacts directly with estrogen, evoking biochemical responses similar to those evoked by estradiol. Meyer and Rapp (1985) found that bovine skeletal muscle contains an estradiol receptor. They also reported that ninety percent of the binding activity of ^{3}H-estradiol was suppressed by estradiol 17-β, zeranol or estrogen; in contrast, estradiol binding was not affected by testosterone, dihydrotestosterone, trenbolone, or progesterone. Furthermore, they demonstrated that skeletal muscle estradiol receptors are identical to uterine estradiol receptors. Their conclusion was that estrogens may exert an anabolic action via direct stimulation of the muscle through estradiol receptors.

Other investigators (Ballard and Francis, 1983; Roeder et al., 1986) have concluded that estradiol and zeranol did not have a direct anabolic effect on L6 myoblasts and myotubes nor did they alter glucocorticoid induced catabolic response in muscle. Trenkle (1983) speculated that the augmentation in protein accretion caused by anabolic estrogens occurred indirectly via modulating endogenous hormone patterns. However, Buttery (1985) reported that estrogens may have a generalized effect on muscle cell through mediating the effects of endogenous hormonal changes. Another suggestion is that estradiol seems to affect muscle protein augmentation in ruminants through elevating peripheral blood concentrations of GH, insulin (Heitzman, 1979) and thyroid hormone (Kahl et al., 1978), each of which has anabolic effects. Likewise, zeranol administration elevated GH and insulin level in peripheral blood (Wangsness et al., 1981; Rhind et al., 1984; Williams et al., 1987). Elsasser et al. (1983) indicated that estradiol and zeranol caused acute pituitary secretion of luteinizing hormone, follicle stimulating hormone, and prolactin. Prolactin is structurally related to GH and has

anabolic effects similar to GH (Bauman et al., 1982). Estrogens also may increase secretion of pituitary hormones through action either at the hypothalamic or pituitary level leading to increased GH secretion. In response to elevated GH levels, insulin levels increase. Insulin has protein anabolic effects in ruminant acting directly on muscle and adipose cell (Prior and Smith, 1982; Florini, 1985; Cross and Belk, 1989). However, at the cellular level, GH effects appear to be mediated by somatomedins (Etherton and Kensinger, 1984; Florini, 1985) which elevate protein synthesis in muscle and enhance bone growth. Another potential site of action of anabolic agent is the adrenal gland (Wiggins et al., 1979 and Trenkle, 1983).

Probable Mode of Action for Androgens.

While estrogens act indirectly via endocrine system, endogenous androgen compounds, (i.e., testosterone and trenbolone acetate) (TBA), increase growth and protein deposition by acting directly on skeletal muscle. The mode of action of these agents is far from clear and several mechanism have been proposed. First, androgens bind to specific muscle receptors in rat, pig and bovine (Snochowski et al., 1981; Sauerwein and Meyer, 1989; Buttery and Sinnett-Smith, 1984). Receptor concentrations vary with muscle type (Buttery and Sinnett-Smith 1984). This suggests that the receptor-steroid complex may cause release of some intracellular mediator which in turn causes synthesis of messenger RNA that migrates to endoplasmic reticulum where it dictates synthesis of protein (Rains, 1992). Another suggestion is that trenbolone and testosterone are antagonists to the normal catabolic action of glucocorticoids; by competing for glucocorticoid receptors of muscle,

they would reduce the catabolic effects of glucocorticoids (Rains, 1992; Hutcheson et al., 1993).

Mayer and Rossen (1975) have demonstrated that testosterone can displace dexamethasone, a synthetic glucocorticoid, from glucocorticoid receptors in rat muscle. Other research has cast doubt on this suggestion. Snochowski et al. (1981) established that muscle from both rats and pigs has distinct glucocorticoid and androgenic receptors with little evidence of cross binding of testosterone to the glucocorticoid receptor. Trenbolone elevates plasma estradiol levels in steers (Galbraith, 1980) and heifers (Henricks et al., 1982). Testosterone increases protein synthesis while trenbolone acetate (TBA) increases protein accretion by decreasing protein degradation (Trenkle, 1987). Animals treated with TBA have suppressed adrenocortical function and have lower cortisol, a hormone produced in the adrenal cortex which decreases protein deposition and growth (Jones et al., 1991; Isaacson et al., 1991). However, TBA has little or no effect on other anabolic hormones. TBA implants in the absence of estrogen reduced weight gain and feed efficiency by 7.3 and 3.9 percent, respectively, compared to TBA implanted with Compudose (Hicks, 1985). Galbraith (1980) detected no change in plasma levels of either GH or insulin in TBA-treated heifers; however, GH levels were lower in TBA-treated steers (Hayden, 1992). Miert et al.(1988) investigated the effects of trenbolone and testosterone on plasma removal rates of sulfamethazine, trimethoprim, and antipyrine in female dwarf goats. They found that TBA implants decreased in the removal rate of the sulfamethazine and that plasma creatinine concentrations were elevated by implants.

Estrogenic and Androgenic Combinations.

Combinations of hormones are used in several implants (Table 1). The rationale of combining two hormones into a single implant is to provide cattle producers with a single implant that combines androgenic and estrogenic activity. Combining trenbolone acetate with various estrogens has increased anabolic responses more than with either anabolic agent alone (Heitzman and Harwood, 1977; Roche and Quirke, 1986; Galbraith and Watson, 1978; Heitzman et al., 1981; Preston, 1975; Pritchard et al., 1990; Preston and Rains, 1993). These additive responses in both performance and carcass traits result in a more dramatic shift than from estrogenic compounds alone (Belk, 1992). The effect of the trenbolone-estrogen combination is due primarily to a decrease in the rate of muscle protein degradation rather than to an increased rate of protein synthesis (Sinnett-Smith et al., 1983; Lobley et al., 1985). Unlike estrogen or TBA alone, the combination may improve performance of bulls (Fisher et al., 1986) although responses generally are much greater in castrated than intact males. TBA and estradiol act synergistically to enhance overall feedlot performance probably through different cellular (receptor) mechanisms (Preston and Rains, 1993). These authors postulated that release rates of TBA and estradiol differ when combined in the same implant as compared to two separate implants. Plasma GH concentration has been elevated by these two in combination (Buttery and Sinnett-Smith, 1984 and Hunt et al., 1991).

Synovex implants, combining estradiol benzoate with either progesterone (for steers) or testosterone (for heifers), will increase growth rate

and protein deposition in cattle and decrease amino acid-N (Preston, 1987). Preston (1987) reported that a combination of Ralgro and Synovex increased growth and protein deposition in cattle and decreased plasma urea and amino acid-N. The combination of Compudose and TBA increased daily gain and improved feed efficiency of implanted steers over either implant alone (Hicks et al., 1985; Preston and Rains, 1993). Compared with negative controls, cattle implanted with Revalor gained 27% faster and produced carcasses with larger ribeye areas and lower marbling scores (Eng, 1986). Anabolic implants tend to promote growth more during the early than the latter phases of finishing. This decrease in the growth rate of implanted animals during the latter half of the finishing period has been reported by Kahl et al. (1978), Schanbacher (1984) and Mathison and Stobbs (1983).

Endogenous Sex Steroids.

In some parts of the world, uncastrated males (bulls) are used for beef production. Advantages include less production of fat and more efficient production of red meat and protein. The gender of an animal affects growth rate, feed efficiency, and carcass composition and quality. Heifers fatten at lighter weights than steers, which in turn fatten at a lighter weights than bulls. Intact males grow faster, require less feed per unit of gain and have a higher percentage of edible cuts than steers (Field, 1971) with less fat (Seideman et al., 1982). Unfortunately, bullock carcasses have lower quality grades and fall into a different classification than steers and heifers. Administering endogenous estrogens may hasten the onset of fattening in cattle as indicated by composition differences between steers and heifers (Breidenstein et al.,

1963; Bradley et al., 1966 and Mukhoty and Berg, 1971). One application of this difference among genders (bulls, steers and heifers) is obvious. When cattle enter their phase of rapid fat growth, they need to be slaughtered. This means that heifers should be slaughtered at a lighter weight than steers which in turn should be slaughtered at a lighter weight than bulls.

Exogenous Sex Steroids.

The effects of exogenous anabolic hormones on carcass parameters is dependent upon gender. Steers have very little natural estrogen and androgen is low due to castration. In the intact heifer, estrogen levels fluctuate and androgen levels are very low. Thus, estrogen is the primary androgen needed to enhance growth of steers making androgens secondary; in contrast, androgen is the primary and estrogen the secondary hormone needed to replace or supplement in heifers (Rains, 1992; Hutcheson, 1993).

Young bulls may be ideal for producing lean meat. However, the aggressive behavior of bulls and their low quality grades and higher incidence of darker cutting beef reduce the feasibility of producing beef from bulls. Because steers do not produce large quantities of anabolic hormones endogenously, stimulation by exogenous agents readily produces a response (Cross and Belk, 1989). Zeranol implants have been recommended to reduce libido and other masculinity problems (Corah et al., 1979; O'Lamhna and Roche, 1984; Chaudhary et al., 1985; Fisher et al., 1986). Implanting bulls with zeranol increased growth rate, increased ribeye area (Vanderwert et al., 1985b) and increased the incidence of head butting and mounting activity (Newman et al., 1990). Estrogen implants in bulls increased carcass fatness

Table 1. Trade Name, Hormonal Component, and Dose of Growth Promotants Approved for Feedlot Cattle in the U.S.[a]

Trade Name	Hormonal Component(s)	Dose	Target Animal
Compudose®	Estradiol-17β	24 mg	All cattle
Finaplix®-H[b]	Trenbolone acetate	200 mg	Heifers < 181 kg
Finaplix®-S[b]	Trenbolone acetate	140 mg	Steers
Implus ®-H[c]	Estradiol benzoate and Testosterone propionate	200 mg and 20 mg	Heifers
Implus®-S[c]	Estradiol benzoate and progesterone	200 mg and 20 mg	steers
Revalor®[b]	Estradiol-17β and Trenbolone acetate	28 mg and 40 mg	Steers
MGA®[c]	Melengestrol acetate	0.25 to 0.5 mg	Heifers
Ralgro®[d]	Zeranol	36 mg	All Cattle
Synovex®-C[e]	progesterone Estradiol benzoate	100 mg 10 mg	Cattle < 181 kg
Synovex®-H[e]	Testosterone propionate and Estradiol benzoate	200 mg and 20 mg	Heifers > 181 kg
Synovex®-S[e]	Progesterone and Estradiol benzoate	200 mg and 20 mg	Steers >181 kg

[a] Adapted from Eli Lily, Indianapolis, IN
[b] Hoechst-Roussel Agri-Vet Col., Somerville, NJ
[c] Upjohn, Kalamazoo, MI
[d] Mallinckrodt Veterinary; Inc., Terra Haute, IN
[e] Fort Dodge Animal Health, Overland Park, KS

(Seideman et al., 1985; Newman et al., 1990). Synovex-implanted bulls had higher fat thicknesses at the 12 rib and the less desirable yield grades than bulls implanted with Compudose or Ralgro (Gordon et al., 1986). Ralgro-implanted bulls had less internal and external carcass fat than Compudose and Ralgro-implanted bulls. Implanting intact males with Ralgro increased carcass fatness and quality grade to the level of the implanted steers (Calkins et al., 1986).

Effect of Anabolic Steroids on Carcass Traits

The effect of anabolic implants on carcass merit has been investigated in several trials. The major factors of interest include dressing percent, hot carcass weight (weight of carcass entering the cooler), fat thickness (fat opposite the ribeye and over the entire carcass), % KPH fat (kidney, pelvic and heart fat) and ribeye area (cm^2).

Dressing percent (DP).

The method for calculating DP must be defined in terms of live and carcass weight conditions and dressing procedure for it to be useful. DP in the US. normally is defined as (hot carcass weight ÷ live weight) x 100. Apple et al. (1991) examined the effects of synthetic hormone implants, singularly or in combinations, on performance and carcass traits of Holsteins using six treatment groups: 1) non-implanted controls; 2) implanted with zeranol; 3) implanted with estradiol benzoate and progesterone; 4) implanted with trenbolone acetate; 5) implanted with trenbolone acetate plus estradiol

benzoate and progesterone (TBA+EP); and 6) implanted with trenbolone acetate plus zeranol. He reported no difference (P > 0.5) in DP among treatment groups. Several other studies indicated no change (P > .05) in DP with implanted compared to non-implanted steers (Borger et al., 1973; Hawkins et al., 1987; Laudert and Davis, 1984; Vanderwert et al., 1985; Stobbs et al., 1988; Bartle et al., 1989; Trenkle, 1991; Tatum, 1994). DP of steers implanted with TBA+Z, TBA+EP and TBA+E2 were similar to that of steers not implanted (Keane and Drennan, 1987).

Differences in DP have been detected in several studies. DP was increased (P < .05) by Synovex-S implanted either once or twice (Bartle et al., 1992b) and by Compudose (Huffman et al., 1991) as compared to non-implanted controls. Finaplix-S alone decreased (P < .05) DP but not when implanted in combination with estrogens (Huffman et al., 1991).

Carcass Weight (CW).

Bartle et al. (1989) reported that Revalor (Trenbolone acetate and estradiol) or a Revalor-Synovex combination implanted twice in British crossbred steers increased carcass weight by 17 kg compared with non-implanted steers when all steers had been fed for 168 days. Cattle implanted with Compudose (Preston et al., 1983) or with estradiol plus TBA (Pritchard et al., 1990) produced 47 kg heavier carcasses compared to non-implanted cattle after being fed for 167 days. Likewise, hot CW of Z, EP, and TBA+EP steers was heavier at 248 days (77d concentrate diet and 171d rolled milo and sorghum) than non-implanted steers or steers implanted with TBA alone (Apple et al., 1991). Botts (1992) evaluated various programs of Synovex-S,

Finaplix-S and estradiol 17-β plus trenbolone acetate in feedlot steers of three distinct breed types. He reported that all implant treatments increased hot CW. Utilizing Synovex-S implants, Huck et al. (1991) reported that carcass weights were heavier than for non-implanted carcass. Combining Finaplix and Synovex-S, Huffman et al. (1991) obtained carcasses with a greater weight than from either Finaplix, or Synovex-S as single implants. However, estrogenic implants of various types often have not increased CW. For example, Compudose did not ($P > .05$) increase CW in several trials (Riley and Pope, 1984; Hicks et al., 1985 and Kercher et al., 1990); likewise, Ralgro did not increase CW in several trials (Borger et al, 1973; Hoffman et al., 1977; Cohen and Cooper, 1983; Loy et al. 1988; Kercher et al. 1990 and Mader; 1994) nor did Synovex-S (Rumsey, 1982; Murray et al., 1983; Riley and Pope, 1984; Loy et al., 1988; Foutz, 1990; Kercher et al. 1990; Huffman et al., 1991; Botts, 1992 and Rumsey et al., 1992). Even Finaplix-S, implanted once or twice without an estrogen, failed ($P > .05$) to increase CW and generally has failed to increase growth rate (Tatum, 1994; Kercher et at., 1990; Apple et al., 1991; Huffman et al., 1991; Hunt et al., 1991 and Bartle et al., 1992). Utilization of Compudose plus Finaplix-S with or without a reimplant of Finaplix-S in *Bos indicus* steers did not ($P > .05$) increase CW (Hicks et at., 1985) . Combination implants of Compudose plus Finaplix-S (Kercher et al. 1990 and Hunt et al., 1991), Ralgro plus Finaplix-S (Kercher et al., 1990) and Synovex-S plus Finaplix-S (Kercher et al., 1990) did not ($P > .05$) increase CW. Breed might be involved in this response; Revalor-S increased ($P < .05$) CW in Holstein and Angus steers but not ($P > .05$) in Angus x Simmental steers (Perry et al., 1991).

Fat Thickness (FT).

Apple et al. (1991) investigated the effect of (Z, EP, TBA, TBA+EP and TBA+ Z) in Holstein steers and detected no change in either actual or adjusted FT from implants. Bartle et al. (1992) reported that steers implanted with trenbolone (TBA) and(or) estradiol had similar ($P > .05$) FT compared to non-implanted steers. However, these results with Revalor or Revalor-Synovex combinations on FT are inconsistent with the research discussed previously (Bartle et al., 1989). Charolais crossbred steers receiving combination androgenic and estrogenic anabolic implants had similar ($P > .05$) FT as non-implanted steers (Johnson et al., 1995). Basson et al. (1985) reported that steers implanted or reimplanted with Z and (or) estradiol plus progesterone had similar ($P > .05$) FT as non-implanted steers.

FT has been increased in other research. Angus steers and bulls receiving Finaplix-S had greater ($P < .05$) FT than non-implanted bulls and steers (Hunt et al., 1991). Hereford x Angus and Gelbvieh cross implanted with estradiol and trenbolone acetate had higher ($P < .05$) FT than controls (Pritchard et al., 1990). These results were supported by those of Wagner et al. (1990). Anderson et al. (1992a) indicated that FT was greater for steers implanted with TBA + E (Finaplix-S and Synovex-S) than steers implanted with estradiol alone. Carcass from TBA+E2 implanted steers were fatter than control steers and had a higher subcutaneous to intramuscular fat ratio (Wood et al., 1986)

Ribeye Area (REA).

Several researchers have reported that implants increase ribeye area. Apple et al. (1991) concluded that longissimus muscles (LM) of carcasses were larger ($P < .05$) for steers implanted with TBA + EP than with Z, TBA, or controls. LM areas of TBA+ Z, TBA+ EP and EP carcasses were similar ($P > .05$). Mean ribeye area was increased by implanting steers with Z (Cohen and Cooper, 1983; McCann et al., 1991) and by EP (Rumsey et al., 1992). Galbraith et al. (1981) concluded that Revalor significantly increased live weight, carcass gain, DP, and REA. Apple et al. (1991) found that steers implanted with TBA+ E2 had greater ($P < .05$) ribeye areas than control steers. Bartle et al. (1989) reported that implanted steers with Revalor-S, Revalor-S reimplanted with Revalor-S, Synovex-S, Synovex-S reimplanted with Synovex-S or Revalor-S reimplanted with Synovex-S all had larger ($P < .05$) ribeye areas than non-implanted steers. Trenkle (1992), Huck et al. (1991), and Foutz et al. (1989a) used combinations of estrogenic and androgenic combination implants; implanted steers had larger ($P < .05$) ribeye areas than steers implanted with TBA alone. REA has been increased by up to ten percent by Revalor implants (Trenkle, 1990). In most studies, the increased REA is associated with an increased CW. Trenkle (1992) evaluated implant programs involving Synovex S, Synovex S-Finaplix S and Revalor S implant programs in feedlot steers and concluded that ribeye area consistently was greater ($P < .05$) for implanted steers than control steers that were not implanted.

REA was not affected ($P > .05$) by implanting steers with Synovex-S and (or) Finaplix-S in a study by Huck et al. (1991). Similarly, Huffman et al.

(1991) evaluated the use of Finaplix and Synovex alone or in combination in 46 yearling Angus; implants had no effect ($P > .05$) on REA. Martin et al. (1987) implanted steers either with Steeroid on day 1, Steeroid on day 1 and day 84 or with Compudose on day 1 and found that implanted steers tended to have larger REA than non-implanted steers. REA has not been affected ($P > .05$) by implanting in a number of trials (Prior et al., 1978; Cohen and Cooper, 1983; and Apple et al., 1991).

Kidney, Pelvic and Heart Fat (KPH).

The effect of anabolic implants on (KPH) has been investigated in a number of studies; effects have been inconsistent. Kercher et al. (1990) simultaneously evaluated the impact of Compudose, Synovex-S, Finaplix-S, Compudose plus Finaplix-S, Synovex-S plus Finaplix-S and Ralgro plus Finaplix-S on KPH. They found no effect of hormone treatments on KPH. Apple et al. (1991) reported that Holstein steers implanted with (Z, EP, TBA, TBA+EP and TBA+ Z) had KPH similar ($P > .05$) to non-implanted steers. These results match findings of Trenkle (1985) and Foutz (1990). In contrast, several workers (Loy et al., 1988; Bartle et al., 1989; Rumsey et al., 1992) have reported that estrogenic implants with or without reimplanting with Synovex-S depressed ($P < .05$) KPH. Steers receiving a zeranol implant had lower ($P < .05$) KPH than non-implanted steers (Hoffman et al., 1977; Loy et al., 1988). British crossbred steers reimplanted with Revalor (TBA) or Revalor-Synovex combinations had lower ($P < .05$) KPH percentage than control steers (Bartle et al.,1989). KPH percentage decreased ($P < .05$) with

Finaplix plus Synovex (Huffman et al., 1991), when Revalor-S was double implanted with Revalor-S or with Synovex-S alone (Bartle et al., 1989).

Marbling Score (MS).

Dosage level, time frame and frequency of implant administration must be considered when evaluating the effect of implant hormones on MS. Several studies have detected no effect of implants on MS (Hicks et al., 1985; Foutz et al., 1989b; Faulkner et al., 1991).

In contrast, in several studies, implants have decreased ($P < .05$) MS. Implants of Revalor-S, Synovex-S or combination of the two decreased ($P < 05$) MS compared to non-implanted control steers (Bartle et al. 1989). Both TBA and Ralgro decreased ($P < .05$) MS (Bartle et al., 1992a and Mader, 1994). In a study by Busby and Loy (1991) Finaplix-S implanted steers had lower ($P > .05$) MS than non-implanted steers. Implants of Synovex-S (Busby and Loy, 1991) or Finaplix -S (Huffman et al., 1991) and the combination has decreased ($P < .05$) MS (Huffman et al., 1991; Preston et al., 1992).

Yield Grade (YG)

Beef Carcasses are divided into five yield grades (or cutability ratings) with a score of 1 having the highest cutability. The term cutability refers to the percentage of CW in boneless, closely trimmed retail cuts from the round, loin, rib and chuck. These cuts comprise approximately 75% of the carcass weight and 90% of carcass value. YG of the carcass as now used by USDA in the grading system tends to be the best tool to predict yield cuts from the carcass,

the composition of subprimals, and the value differences between carcasses at different fat trim levels (Griffin, 1989). Although yield is important regardless of trim level of subprimal, its greatest impact is for primal cuts because more fat is trimmed from the subprimal cuts. Due to consumer demand for leaner beef, cutability as it relates to yield and composition of subprimals must be closely evaluated (Dolezal, 1995). The YG equation is: YG = 2.5 + (2.5 x adjusted fat thickness) + (0.0038 x hot carcass wt) + (.2 x % KPH) - (.32 x REA) (USDA, 1989). This equation includes the four factors that have the greatest influence on carcass cutability; ribeye area is the only factor whose increase contributes favorably to YG. The effect of implant hormones on each of these factors already has been addressed; discussion here will limited to effects on YG.

Hardt (1995) assigned forty-two heifers and 38 steers from Bos indicus X Hereford to either not be implanted or implanted with Synovex-C within 45 d of birth, and with Synovex-S or -H at weaning and 84 and 169 d postweaning. The YG tended to be improved ($P < .07$) by implants in heifers but not in steers. TB+EP implanted steers tended to have lower ($P = .07$) numerical YG than EP, Z, or C-implanted steers (Apple et al., 1991). YG was decreased ($P < .05$) in Synovex-S implanted steers (Rumsey et al., 1992 and Trenkle, 1991; 1993) but in the latter study, the effect was not ($P > .05$) significant. Steeroid or Compudose implanted steers had higher ($P < .05$) cutability than controls (Martin et al., 1987). In each of these studies, the decrease (improvement) in YG was associated with an increased ribeye area.

Adams et al. (1990) investigated the effect of anabolic steroid implants on feedlot performance and carcass composition and quality traits of mixed English heifers; Synovex-H increased ($P < .05$) CW, but did not alter ($P > .05$)

carcass quality and yield. YG was not affected ($P > .05$) by implanting steers with (trenbolone acetate and estradiol) or implanting heifers with Synovex-H (Bartle et al., 1991). YG was not affected by implants in several trials (Gill et al., 1987; Foutz et al., 1989a; Busby and Loy, 1991; Preston et al., 1992; Mader, 1994; Johnson, 1995).

In some trials, YG has been increased by implants. Compared to non-implanted steers, Finaplix-S + Synovex-S implanting steers in separate ears tended to have increased ($P < .05$) YG as compared to placing implants in the same ear (Anderson et al., 1992a). TBA+E implanted steers had greater fat thickness and ribeye area ($P < .01$) than E-implanted steers (Anderson et al., 1992b). Estradiol \ testosterone implanted steers had higher ($P < .05$) YG than non-implanted heifers (Bartle et al., 1991). This finding is supported by research by Wagner et al. (1990) and Pritchard et al. (1990). The increased YG in these studies has been associated with an increased FT.

In summary, many factors singly and in combination can alter the response of cattle to estrogenic and androgenic implants. Among these factors are the type of animal (gender, breed class, age), days on feed and implant and re-implant time relative to slaughter, as well as the type and concentration of compounds present in the implant. In addition, results can be manipulated by selection of the slaughter time (equal time on feed vs. equal FT vs. equal degree of marbling). Although most experiments are conducted with an equal time on feed, commercial cattle that are implanted often are fed for a different number of days than non-implanted cattle. Proper selection of slaughter date may help producers to attain optimum quality and YG grade responses to implants and thereby enhance meat quality and profit.

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EFFECTS OF IMPLANTS ON BOXED-BEEF YIELDS FROM FEEDLOT STEERS

M.T. Al-Maamari, H.G. Dolezal, E.S. Johnson, T.L. Gardner, B.A. Gardner, D. R. Gill, P.T. Anderson and R.L. Botts

ABSTRACT

Forty-eight pens of yearling crossbred steers (n = 528) were blocked by initial weight (319 kg) and allocated to one of four implant treatments: nonimplanted = CON, ET = 28 mg estradiol benzoate (EB) plus 200 mg trenbolone acetate on day 0, ETET = ET implanted on day 0 and reimplanted on day 61, and SET = 20 mg EB and 200 mg progesterone on day 0 and ET administered on day 61. Sixteen pens of cattle (11 head/pen) were assigned to three slaughter groups (176 head/slaughter group). All steers were fed a high concentrate diet for either 127, 148 or 169 days. Following slaughter, two carcasses from each pen (n = 96) were fabricated into boneless subprimals with three different fat thicknesses (2.5, 0.6 and 0.0 cm) to determine boxed beef cutout yield. Treatment effects noted for carcass grade traits in the overall study were maintained in this subsample of carcasses. Total boxed beef yield per carcass at all levels of fat trim was increased ($P < .05$) by implants with the largest increase noted for the ETET treatment. However, percentage yield of boxed beef products, trimmable fat and bone with 0.0 cm fat were similar ($P > .05$) for CON, ET, ETET and SET, respectively. Cutability components for implant treatment groups were compared at various endpoints: a constant slaughter weight, a constant fat thickness, and a constant marbling score.

Adjusted to an equivaluent carcass weight of 555.7 kg, steers doubly implanted with ET yielded more ($P < .05$) total pounds of major subprimals and total boxed beef than carcasses from nonimplanted steers; however, no ($P > .05$) differences were detected among CON, SET and ET treatment groups. Implanting reduced ($P < .05$) pounds of trimmable fat. Adjusted to a constant fat thickness (0.6 cm), implanting increased weight in boxed beef and of bone with more boxed beef from steers reimplanted with ET than implanted only once with ET. Adjusted to a constant marbling score of small[59], trimmable fat weight yield was greater ($P < .05$) for implanted steers. Results indicate that implanting does not alter carcass percentage composition at a specified time endpoint; however, implanting increases weight of lean without increasing the amount of trimmable fat.

Introduction

Performance and cutability of beef cattle are of major financial interest to cattle producers. For beef to remain competitive in the retail case, it is essential to maximize the animal's ability to grow and to convert feedstuffs into highly palatable, nutritious meat. The beef industry must produce edible beef as efficiently as possible. In the US beef industry, over 3 billion pounds of excess fat are trimmed each year (Allen et al., 1976). Smith et al (1992) indicated that $279.82 was lost for each animal fed due to inefficiences of production; this value dropped to $276.59 in 1995 (Smith et al., 1995). Ultimately passed on to the consumer, these costs have reduced beef's market share. The primary methods to improve beef quality according to the 1991 National Beef Quality Audit are to: reduce excessive external fat; decrease excessive seam fat; improve cutability; and increase the

understanding about the value of closely-trimmed products. Research efforts to improve the market position of beef have focused on specific production and management schemes that may result in a leaner carcass. Cattle with a larger mature size, feeding more roughage, and trimming fat from the carcass prior to retailing all can result in a leaner carcass

Although each of these methods separately or in combination can result in leaner retail beef, none has greater potential for growth regulation than growth-promoting hormones. Anabolic implants (both estrogenic and androgenic) enhance live weight gain in feedlot cattle. Trenbolone acetate (TBA) in combination with estrogenic implants increases carcass weight gain beyond estrogenic implants alone (Wagner et al., 1990). The goal of this study was to determine the effect of estrogenic and(or) androgenic implants administered at the start of the finishing phase and(or) at reimplant time on carcass grade traits and boxed beef yield of subprimal cuts.

Material and Methods

Five hundred twenty eight Charolais crossbred yearling steers from a single source (initial weight 319 kg), were selected for this implant trial. Upon arrival at a commercial feedlot, steers were individually weighed, tagged, processed and blocked into four weight groups. Implant treatment assignments included CON = nonimplanted control; ET = 28 mg estradiol benzoate plus 200 mg trenbolone acetate on day 0; ETET = ET administered on day 0 and reimplanted on day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 and a reimplant of ET on day 61. Each treatment consisted of four pens of 11 steers designated for three slaughter dates (127, 148 and 169 days). Quality and yield grade data were collected

approximately 66 hr after slaughter (USDA, 1989). Two steers were selected randomly prior to slaughter from each of the 48 pens for carcass fabrication to determine yield of boxed beef. The left side of each carcass in the subsample (n = 96) initially was fabricated into the four major wholesale cuts (round, loin, rib and chuck) and later was fabricated into subprimals to determine weights at three different subcutaneous fat trim thicknesses (2.5, 0.6 and 0.0 cm). Boxed beef yields were assessed as major subprimals (inside round, gooseneck round, knuckle, top sirloin butt, strip loin, tenderloin, lip-on ribeye, chuck roll, and clod), minor subprimals, lean trim (50:50 and 75:25 lean: fat), and total boxed beef (major subprimals + minor subprimals + lean trim). All subprimals except for two small cuts (short ribs and back ribs) were boneless.

The statistical model included weight block, implant treatment, days-fed and the implant treatment x days-fed interaction. Additionally, contrasts were used to examine linear or curvilinear effects over days-fed for dependent variables of interest both overall and within implant treatment groups. Dependent variables were assessed at four constant end points: days-fed (148), slaughter weight (555.7 kg), fat thickness (0.60 cm), and marbling score ($small^{59}$). Considering the serial slaughter design of this study, overall implant treatment means represent comparisons at a constant time (148 days-fed). Appropriate days-based plus weight-based regression equations for cutability traits were used to predict trait values at the other three endpoints: constant slaughter weight (555.7 kg), constant fat thickness (0.6 cm) and constant marbling score ($small^{59}$). Appropriate based regression equations were used to predict the days necessary for each treatment to achieve these three endpoints. These means were separated via least squares means analysis. Tukey's HSD procedure was used to test values after adjusting error

variances for regression estimates along the days or weight-based lines. Significance was reported at the .05 probability level.

Preliminary analyses indicated that both ribeye area and kidney, pelvic and heart fat (KPH) deviated from the overall linear regression; therefore, subclass regression coefficients were used for adjustment of this variables using the following model.

$$\hat{Y}_i = b_0 + b_1 D_i$$

where:

$\hat{Y}_i$ = predicted value of the observation,
b_0 = intercept for the i^{th} treatment,
b_1 = linear coefficient for the i^{th} treatment, and
D_i = days effect for the i^{th} treatment.

The remaining weight variables were adjusted using a dummy variable technique using the following model:

$$\hat{Y}_i = b_0 + b_1 D_i + b_2 D_i^2$$

where:

$\hat{Y}_i$ = predicated value of the observation,
b_0 = intercept for the i^{th} treatment,
b_1 = linear coefficient for the i^{th} treatment,
D_i = days effect for the i^{th} treatment,
b_2 = constant quadractic coefficient,
D_i^2 = days^2 for the effect of the i^{th} treatment.

The above model was solved to predicted the days on feed necessary to achieve the desired endpoint. The independent variable identified to be used

in the regression models was carcass weight which accounted for most of the variation in the dependent variables of interest. The model utilized was:

$$\hat{Y}_i = b_0 + b_1 W$$

where:

$\hat{Y}_i$ = predicted value of the dependent variable for the i^{th} treatment,
b_0 = intercept for the i^{th} treatment,
b_1 = linear coefficient for the i^{th} treatment, and
W = carcass weight.

All predicted values were calculated from the above regression equation using the same independent variable in order to standardize the analysis and make it more applicable to both production and producer sectors.

The use of multiple endpoints provides greater insight for producers to further examine the effect of implant treatments on steers slaughtered at all four endpoints to market cattle. Prior to the calculation of predicted values, regression analyses were utilized to test for interactions within treatment groups across all days-feed. Due to the fact that the independent variables (treatments) are qualitative, a dummy variable regression technique was utilized to determine differences between individual equations for slope and intercept using slaughter weight as a covariant among groups. Contrasts (CI) were conducted for effects of controls compared with all implants. Additionally, contrasts (EI) were conducted for effects of single (ET) versus double (ETET) implants. Significance was reported at the .05 probability level.

Results and Discussion

Carcass traits. Least squares means for slaughter and carcass grade traits stratified by implant treatment at a constant number of days fed (148 days) are presented in Table 2. These values are only for carcasses of the subset (n = 96) used for fabrication. Carcasses from implanted steers had heavier ($P < .05$) carcass and slaughter weights than carcasses from non-implanted steers (control). Implanting has increased carcass and slaughter weights in several previous trials including those reported by Bartle et al. (1989), Foutz et al. (1989b), Apple et al. (1991), Huck et al. (1991) and Mader (1994). Trenkle (1990) and Bartle et al. (1989) have also observed that reimplanting with TBA increased slaughter and carcass weights of steers.

Dressing percentage was not significantly different among treatments in this subset, though there was a trend for implants to increase dressing percentage with ETET and SET having the highest numerical value, respectively. Apple et al. (1991) reported that dressing percentage in TBA and (or) estrogen-treated steers was not significantly different from that of untreated steers (control). However, steers from the overall study (n = 514) implanted with ETET had higher ($P < .05$) dressing percentages than all other treatment groups. These results are in agreement with the findings of Galbraith et al. (1981) who reported that dressing percentage was greater for TBA+Estradiol implanted steers than non-implanted steers.

Carcasses from implanted steers had slightly greater ($P < .05$) skeletal maturity. Overall maturity was more ($P < .05$) advanced for SET implanted steers than controls. However, regardless of the significance of the higher maturity scores of SET, all scores for implanted steers were well within "A" and thereby should have not cause carcass discounts.

Longissimus muscle areas at the 13th rib of steers were increased by implants. This observation agrees with that of Apple et al. (1991) who reported that carcass from TBA + EP steers had larger ($P < .05$) longissimus muscle areas and Galbraith et al. (1981) who found that Revalor implants increased ribeye muscle area. Trenkle (1992), Huck et al. (1991), and Foutz et al. (1989a) also reported that an estrogen plus androgen implant increased ($P < .05$) the ribeye areas of steers.

Percentage KPH was similar ($P > .05$) in all implanted treatments although numerically, implanted steers tended to have lower KPH. No difference due to implants was detected in studues by Kercher et al. (1990), Apple et al. (1991), and Pritchard et al. (1990) however implanting significantly decreased KPH in studies by Bartle et al. (1989), Loy et al. (1988), and Rumsey et al. (1992) in studies with estrogen implants and (or) reimplants with Synovex-S.

ET implanted steers had greater ($P < .05$) measured fat thickness over the 13th rib than non-implanted steers. Similar results were reported by Wood et al. (1986) who found that TBA+Estradiol implants increased fat thickness and the subcutaneous to intermuscular fat ratio. Pritchard et al. (1990) also reported that Hereford x Angus and Gelbvieh crossbred steers implanted with estradiol and trenbolone acetate had greater ($P < .05$) fat thicknesses than unimplanted controls. Additionally, Hunt et al. (1991) found that Angus steers and bulls receiving Finaplix-S had greater ($P < .05$) fat thicknesses than non-implanted bulls and steers.

Yield grade was not significantly different among treatments, although the mean yield grade and adjusted fat thickness for carcasses from ET tended to be higher than all other treatment groups. These results were consistent

with those of Gill et al. (1987), Foutz et al. (1989a), Adams et al. (1990), Busby and Loy (1991), Bartle et al. (1991), Preston et al. (1992) and Mader (1994) each of whom found no effect of implants on yield grade of steers. In contrast, Rumsey et al. (1992) reported that yield grade was decreased ($P < .05$) by Synovex-S implants.

Non-implanted steers had higher ($P < .05$) marbling scores than ETET implanted steers. This finding matches that of Bartle et al. (1989) who reported that implants of Revalor-S, Synovex-S or combination of the two decreased ($P < .05$) marbling scores compared to non-implanted control steers. Reimplanting with TBA has reduced in marbling scores in studies by Bartle et al. (1989), Hicks et al. (1985) and Foutz et al. (1989a). In contrast, Hunt et al. (1991) found not effects on marbling by implanting bulls or steers with trenbolone acetate and estradiol. However, even though the double ET implant resulted in the lowest marbling score, marbling score means for all implant treatments were well within the small classification. Although implants had effects on marbling and consequently on quality grade, dosage and time of implant administration relative to slaughter date and number of days fed may have greater impact on these measurements. Cattle implanted with TBA may need more time on-feed and(or) weight to reach the same quality grade as control steers.

Steers that received no implants (control) had less ($P < .05$) pronounced masculinity (bullock) scores than ETET. These results agree with those of Foutz et al. (1989a; 1990). However, the means for all treatments were between 4 (slight bullock tendencies) and 5 (no bullock characteristics); thereby, these differences should be of minor concern.

Constant Time-On-Feed. Time-constant endpoints are used frequently in feedlot marketing programs across the U.S. Comparisons made at this endpoint should reveal absolute differences in tissue growth associated with implant treatment groups over a specified period of feeding a high concentrate diet. Recall that all steers were blocked by weight and assigned randomly to implant treatment groups at the onset of the finishing phase. Mean initial weights among treatment groups (CON = 317.1, ET = 316.6, ETET = 315.7, and SET = 316.2 kg) for this subset were not ($P > .05$) different. Therefore, differences in final weights and measurements indicate that implants increase weight of lean without increasing the amount of trimmable fat.

Least squares means by implant treatment group for boxed beef lean, fat trim, and bone at the three different degrees of fat trim are presented in Table 3. Previously cited differences in weight as well as similarities in external fatness associated with implant treatments were maintained through boxed beef yields. Carcasses from implanted steers produced more total pounds of major and minor subprimals, lean trim, total boxed beef, and bone at all three levels of trimmable fat. Likewise, no differences ($P > .05$) were detected among implant treatment groups for weights of trimmable fat, regardless of the severity of trim.

These results imply that implanting does not alter composition of gain to a specified time endpoint; however, implanting increased weight of salable lean without increasing the amount of trimmable fat.

Subprimal Yields. Percentage least squares means of boneless, closely-trimmed subprimals (0.0 cm) expressed as percentage of side weight are presented in Table 4. Carcasses from ETET implanted steers yielded numerically higher major and minor subprimals than non-implanted steers. No

significant differences were detected among implant treatments even though carcasses from cattle implanted with ETET and SET tended to have higher yields than carcasses from cattle given a single ET implant. Likewise, implant treatments yields from SET and ET exhibited higher positive numerical responses than controls, yet most differences were too slight for significance.

Trimmed gooseneck round yields were significantly higher ($P < .05$) for ETET and SET implanted than control steers. Similarly, trimmed boneless chuck yields for all carcasses from implanted steers compared to controls. These results are in agreement with Foutz (1990) who reported that TBA implants increased trimmed boneless chuck yield.

Data suggest that overall, administration of ETET implants enhanced ($P < .05$) cumulative subprimals yields. Furthermore, aside from gooseneck round and chuck lean yields, implant treatments had limited effect on the relative distributions of lean between the other major carcass primals (knuckle, inside round, loin, and rib) even though lean tissue growth was increased.

Table 4 illustrates yields of subprimals expressed as percentage of side weight. Percentage yields of boxed beef products, trimmable fat and bone at the 0.0 cm fat trim level were similar ($P >. 05$) for CON, ET, ETET and SET, respectively. These results suggest that implanting did not alter percentage composition of carcass gain to specific time endpoint.

Constant Slaughter Weight. Weight-constant comparisons should magnify tissue development differences attributable to implant treatments. Predicted least squares means at a constant slaughter weight for carcass component yields stratified by implant treatment groups are reported in Table 6. Carcasses from steers doubly implanted with ET (ETET) yielded more ($P <$

.05) total pounds of major subprimals and total boxed beef than carcasses from nonimplanted steers. Differences were not significant among implant treatments for total boxed beef and major subprimals yields among CON, SET and ET treatment groups. Carcasses from all implanted steers yielded fewer ($P < .05$) total pounds of fat than control carcasses at all levels of trim (2.5, 0.6 and 0.0 cm). Yields of minor subprimals, lean trim, and bone were not affected ($P > .05$) by implant treatments when comparisons were made at a constant slaughter weight.

Constant Fat Thickness. Comparisons at a constant fat thickness contrasts differences in developmental patterns independent of stage of fattening. At this endpoint, carcasses from implanted steers still yielded more ($P < .05$) boxed beef (total, major subprimals, minor subprimals, and lean trim) at all trim levels as well as more bone than carcasses from nonimplanted steers (Table 7). As expected, no differences were detected ($P > .05$) among implant treatment groups for pounds of trimmable fat at a constant fat thickness endpoint. Carcasses from steers reimplanted with ET tended to produce more total pounds of major subprimals and, accordingly, more total boxed beef than carcasses from steers implanted with ET only at the onset of the finishing phase.

Constant Marbling Score. Comparisons at a constant marbling score (level of quality) are presented in Table 8. Such comparisons reflect an economically important bench-mark for the beef industry. Treatment effects at this endpoint were similar to comparisons made at a constant fat thickness except that carcasses from implanted steers yielded significantly more trimmable fat (2.5, 0.6, and 0.0 trim levels) than carcasses from nonimplanted steers. Furthermore, ETET and SET implanted steers were predicted to

require an additional 44 days-on-feed and ET implanted steers need 35 more days to deposit the same amount of marbling as the non-implanted steers.

In additional to enhancing muscle growth, Anabolic implants also may affect skeletal growth. Data show that changes in total bone weight were relatively proportional to weights of muscle; implanted steers had greater ($P < .05$) bone weight than non-implanted steers.

Implications

Results of this study indicate that steers receiving an estrogen plus androgen implants had greater boxed beef yield level regardless of the extent of fat trimming. Implanting did not appear to alter composition of gain (tissue percentage basis) in time-constant comparisons. Implants increased weight of salable lean without increasing the amount of trimmable fat.

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Table 2. Least squares means for slaughter and carcass traits stratified by implant treatment at a constant time on-feed (148 d)

Trait	Implant treatment[a]				
	CON	ET	ETET	SET	Effect[b]
No. of Sides	25	24	25	22	
Slaughter, weight, kg	540.2[g]	588.4[f]	584.1[f]	584.1[f]	CI
Hot carcass weight, kg	347.3[g]	379.9[f]	380.7[f]	380.7[f]	CI
Dressing percentage	64.4	64.5	65.2	65.0	
Carcass maturity[c]					
Skeletal	129.2[g]	150.9[f]	156.4[f]	166.4[f]	CI
Lean	142.4	145.3	144.3	160.6	CI
Overall	135.8[g]	148.1[fg]	150.3[fg]	163.5[f]	CI
Marbling score[d]	490.5[f]	454.1[fg]	410.3[g]	442.5[fg]	
Fat thickness, in	1.40[g]	1.85[f]	1.65[fg]	1.63[fg]	
Adjusted fat thickness, cm	1.47	1.96	1.70	1.75	CI
Ribeye area, sq cm	76.77[g]	83.23[f]	85.81[f]	85.16[f]	CI
KPH, %	2.95	2.81	2.63	2.78	CI
Yield grade	3.63	4.02	3.64	3.72	
Masculinity score	4.55[f]	4.45[f]	4.05[g]	4.13[f]	CI EI

[a]Implant treatments: CON = Control (non-implanted); ET = 28 mg estradiol benzoate and 200 mg trenbolone acetate on day 0; ETET = ET on day 0 and day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 and ET reimplanted on day 61.

[b]Contrast effect: CI ($P < .05$) = CON versus all implants; EI ($P < .05$) = ET versus ETET.

[c]Carcass maturity score: 100 to 199 = "A" maturity, approximately 9 to 30 months of chronological age at slaughter (USDA, 1989).

[d]Marbling score: 400 to 499 = "small" degree, the minimum requirement for U.S Choice (USDA, 1989).

[e]Masculinity score: 5 = slight; 1 = severe bullock carcass characteristics.

[f,g] Means in the same row with a common superscript letter are not different ($P > .05$).

Table 3. Least squares means for boxed beef lean, fat trim and bone for the 2.5, 0.6 and 0.0 cm fat trim specifications stratified by implant treatment at a constant days-fed (148 d)

	Implant Treatment[a]			
Trait	CON	ET	ETET	SET
Number of sides	25	24	25	22
Boxed beef total, kg				
2.5 cm	243.5[c]	268.1[b]	271.4[b]	267.8[b]
0.6 cm	231.3[c]	255.5[b]	258.4[b]	255.1[b]
0.0 cm	225.3[c]	249.5[b]	252.2[b]	248.5[b]
Major primals, kg				
2.5 cm	145.6[c]	160.3[b]	164.4[b]	162.4[b]
0.6 cm	122.1[c]	135.1[b]	138.5[b]	136.3[b]
0.0 cm	112.5[c]	124.7[b]	127.8[b]	125.6[b]
Minor subprimals, kg				
2.5 cm	59.8[c]	65.5[b]	65.1[b]	64.9[b]
0.6 cm	57.7[c]	63.5[b]	62.9[b]	63.0[b]
0.0 cm	53.7[c]	59.4[b]	58.7[b]	58.6[b]
Lean trim, kg				
2.5 cm	38.1[c]	42.2[b]	42.0[b]	40.6[b]
0.6 cm	51.5[c]	57.0[b]	57.0[b]	55.8[b]
0.0 cm	59.1[c]	65.5[b]	65.6[b]	64.3[b]
Fat trim, kg				
2.5 cm	54.2	56.7	54.5	56.2
0.6 cm	66.4	69.3	67.5	68.9
0.0 cm	72.4	75.3	73.7	75.4
Bone, kg	49.5[c]	55.2[b]	54.9[b]	53.7[b]

[a] Implant treatments: CON = control (non- implanted); ET = 28 mg estradiol benzoate and 200 mg trenbolone acetate on day 0; ETET = ET on day 0 and day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 and ET reimplanted on day 61.

[b,c] Means in the same row with a common superscript letter are not different ($P > .05$).

Table 4. Percentage side weight least squares means for the 0.0 cm fat trim specification stratified by implant treatment at a constant time on feed[b]

Trait	Implant Treatment[a]			
	C	ET	ETET	SET
No of sides	25	24	25	22
Boxed beef total, kg	65.0	65.7	66.3	65.9
Major primals, kg	32.5	32.8	33.6	33.3
Minor subprimals, kg	15.5	15.6	15.5	15.5
Lean trim, kg	17.0	17.3	17.2	17.0
Fat trim,	20.8	19.8	19.3	19.9
Bone, kg	14.3	14.5	14.4	14.2

[a] Implant treatments: CON = nonimplanted control; ET = 28 mg estradiol benzoate and 200 mg trenbolone acetate on day 0; ETET = ET on day 0 and day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 and reimplanted with ET on day 61.

[b] Means in the same row with a common superscript letter are not different ($P > .05$).

Table 5. Percentage least squares means of boneless, closely-trimmed (0.0") boxed beef major and minor subprimals stratified by implant treatment

Trait	Implant Treatment[a]			
	C	ET	ETET	S/ET
No. of Sides	25	24	25	22
Major Primals	67.7[e]	67.7[e]	68.5[d]	68.2[de]
Knuckle	5.3	5.3	5.3	5.2
Inside Round	10.2	9.9	10.1	10.1
Gooseneck Round	11.8[e]	12.0[de]	12.1[d]	12.2[d]
Top Sirloin Butt	5.5	5.4	5.5	5.6
Strip Loin	5.6	5.7	5.7	5.7
Tenderloin	3.1	3.0	3.1	3.1
Ribeye (lip-on)	7.1	7.0	7.0	7.0
Clod	9.4	9.4	9.3	9.5
Chuck Roll	9.6[f]	10.1[de]	10.4[d]	10.0[e]
Minor Subprimals	32.3[d]	32.3[d]	31.5[e]	31.8[de]

[a] Implant treatments: CON = nonimplanted control; ET = 28 mg estradiol benzoate and 200 mg trenbolone acetate on day 0; ETET = ET on day 0 and day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 and reimplanted with ET on day 61.

[d,e,f] Means in the same row with a common superscript letter are not different ($P > .05$).

Table 6. Predicted least squares means for boxed beef lean, fat trim and bone for the 2.5, 0.6 and 0.0 cm fat trim specifications stratified by implant treatment at a constant slaughter weight (555.7 kg)

Trait	Implant Treatment[a]			
	CON	ET	ETET	SET
Days fed	161	133	131	130
Number of sides	25	24	25	22
Boxed beef total, kg	250.8^{c}	252.1^{bc}	257.0^{b}	253.3^{bc}
2.5 cm	237.6^{c}	241.2^{bc}	245.0^{b}	241.9^{bc}
0.6 cm	231.4^{c}	235.7^{bc}	239.3^{b}	235.6^{bc}
0.0 cm				
Major primals, kg				
2.5 cm	149.9^{c}	150.0^{c}	154.5^{b}	153.2^{bc}
0.6 cm	125.0^{c}	127.6^{bc}	130.9^{b}	130.0^{bc}
0.0 cm	115.1^{c}	118.0^{bc}	121.1^{b}	119.8^{bc}
Minor subprimals, kg				
2.5 cm	61.5	61.9	62.2	60.9
0.6 cm	59.2	59.8	60.2	59.0
0.0 cm	55.0	55.9	56.3	54.8
Lean trim, kg				
2.5 cm	39.5	40.1	40.3	39.2
0.6 cm	53.4	53.8	53.9	53.0
0.0 cm	61.3	61.7	61.9	61.0
Fat trim, kg				
2.5 cm	57.5^{b}	49.7^{c}	49.3^{c}	50.7^{c}
0.6 cm	70.7^{b}	61.0^{c}	61.2^{c}	60.3^{c}
0.0 cm	76.9^{b}	66.0^{c}	66.9^{c}	68.4^{c}
Bone, kg	51.3	51.2	52.0	50.3

[a] Implant treatments: CON = control (non- implanted); ET = 28 mg estradiol benzoate and 200 mg trenbolone acetate on day 0; ETET = ET on day 0 and day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 and ET reimplanted on day 61.

[b,c] Means in the same row with a common superscript letter are not different($P > .05$).

Table 7. Predicted least squares means for boxed beef lean, fat trim and bone for the 2.5, 0.6 and 0.0 cm. fat trim specifications stratified by implant treatment at constant tat thickness (0.6 cm)

Trait	Implant Treatment[a]			
	CON	ET	ETET	SET
Days fed	138	132	134	134
Number of sides	25	24	25	22
Boxed beef total, kg				
2.5 cm	238.2^{d}	251.0^{c}	261.4^{b}	256.4^{b}
0.6 cm	226.5^{d}	240.2^{c}	249.0^{b}	244.7^{bc}
0.0 cm	220.6^{d}	234.7^{c}	243.2^{b}	238.3^{b}
Major primals, kg				
2.5 cm	142.5^{d}	149.3^{c}	157.5^{b}	155.1^{b}
0.6 cm	119.9^{d}	127.1^{c}	133.2^{b}	131.3^{bc}
0.0 cm	110.5^{c}	117.6^{b}	123.2^{b}	121.0^{b}
Minor subprimals, kg				
2.5 cm	58.6^{c}	61.6^{b}	63.0^{b}	61.7^{b}
0.6 cm	56.6^{c}	59.5^{b}	61.0^{b}	59.8^{b}
0.0 cm	52.7^{c}	55.7^{b}	57.1^{b}	55.6^{b}
Lean trim, kg				
2.5 cm	37.0^{c}	40.0^{b}	40.7^{b}	39.6^{b}
0.6 cm	50.1^{c}	53.5^{b}	54.8^{b}	53.6^{b}
0.0 cm	57.2^{c}	61.4^{b}	63.0^{b}	61.7^{b}
Fat trim, kg				
2.5 cm	52.3	49.2	50.8	51.8
0.6 cm	64.0	60.3	63.1	61.7
0.0 cm	69.9	65.4	68.9	69.9
Bone, kg	48.2^{c}	50.8^{b}	52.8^{b}	51.0^{b}

[a] Implant treatments: CON = control (non- implanted); ET = 28 mg estradiol benzoate and 200 mg trenbolone acetate on day 0; ETET = ET on day 0 and day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 and ET reimplanted on day 61.

[b,c,d] Means in the same row with a common superscript letter are not different ($P > .05$).

Table 8. Predicted least squares means for boxed beef lean, at trim and bone for the 2.5, 0.6 and 0.0 cm fat trim specification stratified by implant treatment at a constant marbling (small[59])

Trait	Implant Treatment[a]			
	CON	ET	ETET	SET
Days fed	125	160	169	169
Number of sides	25	24	25	22
Boxed beef total, kg				
2.5 cm	228.5^{d}	268.8^{c}	285.9^{b}	281.2^{b}
0.6 cm	218.0^{d}	256.1^{c}	271.9^{b}	266.9^{b}
0.0 cm	212.3^{c}	250.0^{b}	265.3^{b}	260.1^{b}
Major primals, kg				
2.5 cm	136.9^{d}	160.8^{c}	174.5^{b}	170.6^{b}
0.6 cm	116.0^{d}	135.3^{c}	146.3^{b}	141.7^{b}
0.0 cm	107.0^{d}	124.9^{c}	134.7^{b}	130.5^{bc}
Minor subprimals, kg				
2.5 cm	56.4^{d}	65.7^{c}	67.8^{bc}	68.4^{b}
0.6 cm	54.5^{d}	63.6^{c}	65.4^{bc}	66.5^{b}
0.0 cm	50.9^{c}	59.5^{b}	61.2^{b}	61.9^{b}
Lean trim, kg				
2.5 cm	35.2^{c}	42.4^{b}	43.5^{b}	42.2^{b}
0.6 cm	47.5^{d}	57.2^{c}	60.1^{b}	58.7^{bc}
0.0 cm	54.4^{d}	65.6^{c}	69.3^{b}	67.7^{bc}
Fat trim, kg				
2.5 cm	48.3^{c}	57.3^{b}	59.8^{b}	61.1^{b}
0.6 cm	58.8^{c}	70.5^{b}	73.8^{b}	72.7^{b}
0.0 cm	64.5^{d}	76.1^{c}	80.4^{b}	82.2^{b}
Bone, kg	45.9^{c}	55.7^{b}	57.9^{b}	56.7^{b}

[a] Implant treatments: CON= control (non- implanted); ET = 28 mg estradiol benzoate and 200 mg trenbolone acetate on day 0; ETET = ET on day 0 and day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 and ET reimplanted on day 61.

[b,c,d] Means in the same row with a common superscript letter are not different ($P > .05$).

APPENDIX

Table 9. Least squares means for boxed beef lean, fat trim, and bone for 2.5, 0.6 and 0.0 cm fat trim specifications stratified by implant treatment at a constant days-fed (148 d) and adjusted to the overall treatment yield grade distribution

	Implant Treatment[a]			
Trait	CON	ET	ETET	SET
Number of sides	25	24	25	22
Boxed beef total, kg				
1.0 cm	242.4	262.0	270.5	266.4
0.25 cm	230.2	250.7	257.5	253.9
0.0 cm	224.2	244.9	251.4	247.4
Major primals, kg				
1.0 cm	145.0	156.8	163.8	161.3
0.25 cm	121.6	133.4	138.0	135.9
0.0 cm	112.0	123.4	127.4	125.3
Minor subprimals, kg				
1.0 cm	59.6	64.2	64.9	64.4
0.25 cm	57.4	62.2	62.7	62.5
0.0 cm	53.5	58.3	58.6	58.2
Lean trim, kg				
1.0 cm	38.1	41.1	41.9	40.7
0.25 cm	51.3	55.1	56.8	55.7
0.0 cm	58.9	63.3	65.4	64.1
Fat trim, kg				
1.0 cm	54.1	52.3	54.4	54.9
0.25 cm	66.3	63.6	67.4	67.3
0.0 cm	72.3	69.3	71.4	73.8
Bone, kg	49.3	53.9	54.7	53.3

[a] Implant treatments: CON = nonimplanted control; ET = 28 mg estradiol benzoate and 200 mg trenbolone acetate on day 0; ETET = ET on day 0 and day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 and reimplanted with ET on day 61.

Table 10. Percentage least squares means for boxed beef lean, fat trim, and bone for 2.5, 0.6 and 0.0 cm fat trim specifications stratified by implant treatment at a constant days-fed (148 d) and adjusted to the overall treatment yield grade distribution

	Implant Treatment[a]			
Trait	CON	ET	ETET	SET
Number of sides	25	24	25	22
Boxed beef total				
2.5 cm	70.1	71.4	71.3	71.2
0.6 cm	66.6	68.3	67.9	67.9
0.0 cm	64.9	66.8	66.3	66.2
Major primals				
2.5 cm	42.0	42.7	43.2	43.1
0.6 cm	35.2	36.4	36.4	36.4
0.0 cm	32.4	33.7	33.6	33.5
Minor subprimals				
2.5 cm	17.2	17.5	17.1	17.2
0.6 cm	16.6	17.0	16.5	16.7
0.0 cm	15.5	15.9	15.5	15.6
Lean trim				
2.5 cm	11.0	11.2	11.0	10.9
0.6 cm	14.8	15.0	15.0	14.9
0.0 cm	17.0	17.2	17.2	17.1
Fat trim				
2.5 cm	15.6	14.2	14.2	14.6
0.6 cm	19.2	17.3	17.7	17.9
0.0 cm	20.9	18.8	18.7	19.6
Bone	14.3	14.7	14.4	14.2

[a] Implant treatments: CON = nonimplanted control; ET = 28 mg estradiol benzoate and 200 mg trenbolone acetate on day 0; ETET = ET on day 0 and day 61; SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 on day 0 and reimplanted with ET on day 61.

Table 11. Overall frequency distribution for quality grade

Quality grade	% (n)
Prime-	**5.2 (5)**
Choice	**67.7 (65)**
High	6.2 (6)
Average	9.4 (9)
Low	52.1 (50)
Select	**27.1 (26)**
High	7.3 (7)
Average	15.6 (15)
Low	4.2 (4)

Table 12. Frequency distribution for quality grade stratified by days-fed

	Days-fed		
Quality grade	127	148	169
Prime-	**0 (0)**	**3.1 (1)**	**12.5 (4)**
Choice	**62.5 (20)**	**65.7 (21)**	**75.1 (24)**
High	0 (0)	6.3 (2)	12.5 (4)
Average	9.4 (3)a	12.5 (4)	6.3 (2)
Low	53.1 (17)	46.9 (15)	56.3 (18)
Select	**37.5 (12)**	**31.3 (10)**	**12.5 (4)**
High	12.5 (4)	6.3 (2)	3.1 (1)
Average	15.6 (5)	21.9 (7)	9.4 (3)
Low	9.4 (3)	3.1 (1)	0 (0)
Total	**100 (32)**	**100 (32)**	**100(32)**

Table 13. Frequency distribution for quality grade stratified by implant treatment

	Implant treatment			
Quality Grade	CON	ET	ETET	S/ET
Prime-	**12.0 (3)**	**8.3 (2)**	**0 (0)**	**0 (0)**
Choice	**84.0 (21)**	**54.2 (13)**	**60.0(15)**	**72.8 (1**
High	4 .0 (1)	4.2 (1)	8.0 (2)	9.1 (2
Average	16.0 (4)	12.5 (3)	0 (0)	9.1 (2
Low	64 .0 (16)	37.5 (9)	52.0 (13)	54.6 (1
Select	**4.0 (1)**	**37.6 (9)**	**40 (10)**	**27.2 (6**
High	4.0 (1)	16.7 (4)	8.0 (2)	0.0 (0
Average	0 (0)	16.7 (4)	32.0 (8)	13.6 (3
Low	0 (0)	4.2 (1)	0 (0)	13.6 (3
Total	**100 (25)**	**100 (24)**	**100 (25)**	**100 (22)**

Table 14. Overall distribution for yield grade

Yield Grade	% (n)
1	3.1 (3)
2	19.8 (19)
3	41.8 (40)
4	24.0 (23)
5	11.5 (11)

Table 15. Frequency distribution for yield grade stratified by days-fed.

	Days-fed		
Yield Grade	127	148	169
1	9.4 (3)	0 (0)	0 (0)
2	28.1 (9)	18.8 (6)	12.5 (4)
3	53.1 (17)	31.3 (10)	40.6 (13)
4	9.4 (3)	31.3 (10)	31.3 (10)
5	0 (0)	18.8 (6)	15.6 (5)
Total	100 (32)	100.2 (32)	100 (32)

Table 16. Frequency distribution for yield grade stratified by implant treatment

	Implant treatment			
Yield Grade	CON	ET	ETET	S/ET
1	4.1 (1)	0 (0)	4.0 (1)	4.6 (1)
2	24.0 (6)	25.6 (6)	20.0 (5)	9.1 (2)
3	32.0 (8	33.3 (8)	48. (12)	54.6 (12)
4	36.0 (9	12.5 (3)	20.0 (5)	27.3 (6)
5	4.0 (1)	29.2 (7)	8.0 (2)	4.6 (1)
Total	100 (25)	100 (24)	100 (25)	100.2 (22)

Table. 17. Statistical model

Source	DF
Block	3
Trt	3
Days-fed	2
Trt*days-fed	6
Residual	81

Regression Model:

$$\hat{Y}_i = b_0 + b_1 W$$

Where:

$\hat{Y}_i$ = Predicted value of the dependent variable,
b_0 = Intercept,
b_1 = Slope, and
W = Carcass Weight.

Mean Separation

$$\hat{S}2\ Yi = (\ S2Yi + d2iS2bi\ )$$

Where:

$\hat{S}^2Y_i$ = Estimated error mean square

S^2Y_i = Adjusted error mean square

d^2 = (days deviation from 148)^2

S^2b_i = Standard error of day

Tukey HSD test was used