EFFECTS OF COMBINATION ANDROGENIC AND ESTROGENIC ANABOLIC IMPLANTS ON CARCASS TRAITS AND SHEAR FORCE AT THREE POSTMORTEM AGING PERIODS FOR SERIALLY-SLAUGHTERED STEERS

By

EMMA SANDOL JOHNSON

Bachelor of Science
West Texas State University
Canyon, Texas
1976

Master of Agriculture
West Texas State University
Canyon, Texas
1983

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
December, 1995

EFFECTS OF COMBINATION ANDROGENIC AND ESTROGENIC ANABOLIC IMPLANTS ON CARCASS TRAITS AND SHEAR FORCE AT THREE POSTMORTEM AGING PERIODS FOR SERIALLY-SLAUGHTERED STEERS

Thesis Approved:

H Glen Dolezal

Thesis Adviser

Donald R Gill

Stanley E. Bittenbender

Lee L Ebro

Thomas C. Collins

Dean of the Graduate College

ACKNOWLEDGMENTS

I want to thank the Lord for giving me the stability and the soundness of mind to finish this dissertation. I am grateful for His guidance and the many people He had standing in the gap for me during this time. I dedicate this dissertation to my late father, Vernon Johnson, who believed in education and displayed this by always reading and remembering all he read. He believed education would get you off the farm, especially for the girls. I want to thank my mother, Frances Lovelace Johnson, for her love over the years, especially now, when she cannot express that love. I am grateful to my Sissy, Carole Johnson and my brother-in-law, Jim Brooks. Thank you for your love and encouragement during my life and my many college years. Also, a very special dedication to my late husband, Darrell Gwartney, who was encouraging me to pursue the advanced degree, and was willing to move to make it happen. I regret you were not able to make that move.

I want to thank my major advisor, Dr. Glen Dolezal, whose insight was greatly appreciated and to the rest of my committee, Dr. Lea Ebro, Dr. Stanley Gilliland and Dr. Don Gill. I enjoyed your comments, encouragement, and friendship during my years at OSU.

To my special friend and helper, Kris Novotny, you are a God-send and I value you so much. Susan Nickel Hotalling, thanks so much for sharing our lives and home during

our stay at OSU. Linda Guenther and Eric Renfrow, you two are indispensable in encouragement and assistance. Betty Rothermal and Freddie Gant, you are my new found friends and I treasure your help and friendship. Thanks so much to all of my special friends, my fellow graduate students, who were willing to spend hours assisting me with the research projects.

And last, but not least, my love to my son, Micah, who reminds me daily, what is really important in life.

TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

NOMENCLATURE

AOAC	Association of Official Analytical Chemists
^{o}C	degrees Celsius
C	control
cm	centimeters
d	days
^{o}F	degrees Fahrenheit
hr	hours
IGF	insulin-like growth factors
kg	kilograms
lb	pound
mg	milligrams
mm	millimeters
E^2	estradiol - 17ß
EB	estradiol benzoate
EP	estradiol progesterone
MGA	melengestrol acetate
TBA	trenbolone acetate
USDA	United States Department of Agriculture

LD	*Longissimus dorsi*
WBS	Warner-Bratzler Shear
Z	zeranol
S	Synovex®
F	Finaplix®
YG	USDA Final Yield Grade

CHAPTER I

INTRODUCTION

Cattlemen have been using growth promotants for many years to increase cattle production. These growth promotants are anabolic agents that have physiological functions similar to the sex steroids which increase nitrogen retention and protein deposition in the animal (Heitzman, 1979). Growth-promoting hormones are administered as an implant in the United States. Approximately ninety percent of cattle fed in the United States are implanted. Within the commercial feedlots, the rate of usage increases to one hundred percent (NCA, 1994).

Estrogenic implants were the primary growth promotants that had approval in the United States for commercial usage for many years, however, trenbolone acetate (TBA), a synthetic androgenic compound, was recently approved for use in meat animals. The usage of TBA increased as a combination with estrogenic implants during the 1990s (Pritchard et al., 1990). This combination has been noted to increase feedlot performance and lean tissue deposition of beef cattle (Anderson et al., 1991b, 1992). The greatest response from TBA has been in this combination with an estrogenic implant when used once and administered as the terminal implant (Hickman et al., 1994).

Evidence indicates that the implant combinations may cause lowered marbling scores. Increased muscling, even when the amount of marbling and backfat are the same,

changes the proportion of lean to marbling (Rains, 1992). However, the degree of marbling is an element within the U.S. beef grading system to ensure tenderness and palatability for the consumer. This decreased marbling score from TBA usage has created a concern for lowered tenderness from TBA implanted cattle. In an earlier research, Foutz et al. (1989a) indicated there was only a slight decrease in tenderness (shear force) of ribeye steaks from steers implanted and reimplanted with TBA. Other researchers noted no differences in tenderness among implant treatments. Nonetheless, research has been limited in tenderness among steaks from implanted cattle.

With the various feeding and implant strategies being utilized today, timely research is needed to determine the best implant strategy to optimize production while maintaining desired carcass traits and tenderness. The objectives of this research were to compare the effects of combination implants administered at the start of the finishing phase and (or) at reimplant time on 1) carcass grade traits 2) ribeye muscle properties and 3) ribeye muscle tenderness after three aging periods among serially-slaughtered steers.

CHAPTER II

REVIEW OF LITERATURE

Hormones Involved in Growth

Growth Hormone

Growth hormone (GH) is one of the most important regulators in animal growth. Earlier research indicated that GH regulated anabolism. Later research indicates that GH may not be directly responsible for increased synthesis. GH plays a central role in somatomedin production within the animal's liver. The somatomedins are released from the liver and with an action similar to insulin, to promote the uptake of amino acids by muscle cells (Spencer, 1985). Therefore, somatomedins mediate the anabolic effect of GH (Galbraith and Topps, 1981). VanWyk et al. (1974) reported that somatomedins may increase DNA and RNA synthesis. Somatomedins stimulate an increase in number of cells by filling out cells of different tissues and are considered to be the endocrine link to the hormones regulating cell growth. There have been two somatomedins (IGF-1 and IGF-2) identified by Spencer (1985).

An increase in nitrogen retention and muscle mass was reported in steers (Mosely et al., 1982) and in wether lambs (Wagner and Veenhuizen, 1978) from administration of GH. Decreased total fat in carcasses were observed in cattle by investigators: Trenkle and

Topel (1978). Johnson et al. (1993) reported TBA + E2 implanted steers had higher ($P < .01$) serum IGF-1 at day 21 of the feeding trial. Sera from the implanted steers stimulated cultured muscle cell proliferation and had no effect in the non-implanted control steers. Borger et al. (1973a) also reported a significantly ($P < .05$) greater serum level of Growth Hormone in Zeranol-implanted cattle.

Administering GH alone as a growth promotant increased gains and feed efficiency in pigs, accompanied by an increase in loin-eye area and ham protein with decreased back and ham fat (Machlin, 1972). This research has shown that GH has a direct effect on adipose tissue. During animal stress, lipolysis is stimulated and glucose uptake is inhibited. This can act as a protection for the body's protein, to prevent usage of amino acid as energy during stress periods (Galbraith and Topps, 1981).

Insulin

Insulin is an anabolic hormone that regulates carbohydrate metabolism and tissue anabolism during growth. Insulin secretion is regulated in the short term by circulating metabolites, and other hormones (Weekes, 1986). Trenkle and Topel (1978) reported that plasma insulin concentrations were positively correlated with body weight and the proportion of carcass fat, but negatively correlated with carcass muscle. The plasma insulin was unrelated to overall growth rate.

The growth of skeletal muscle depends upon the level of muscle contraction and the nutritional status of the animal. Insulin is a major anabolic factor that stimulates

protein synthesis and inhibits protein degradation to promote deposition of animo acids in new tissue protein (Galbraith and Topps, 1981).

Insulin also increases adipocyte uptake. Plasma hormone concentrations in pigs and ruminants are indicative of a positive association between insulin and carcass fatness (Spencer, 1985).

Thyroid Hormone

Thyroid hormones are considered essential for normal growth and skeletal maturation. Growth hormone and thyroprotein were administered to wether lambs for a period of 98 to 112 days. The thyroprotein alone had no effect on ADG, feed gain ratio, protein gain or plasma GH. But in combination with GH, there was a substantial increase in protein and when used alone, a decrease in fat deposition. This study indicated that thyroprotein alone decreased only fat deposition (Wagner and Veenhizen, 1978).

In a recent study, Synovex-S® was implanted on day 0, day 30; and day 60. The small increases noted in thyroid concentrations are a result of estrogen treatment. But, this is not a primary factor that causes increased protein deposition in implanted steers (Rumsey et al., 1992)

Glucocorticoids

Glucocorticoids are considered to be a growth inhibiting steroids that act on cells directly. They also bind to a specific receptor protein found in target cells, rather than effecting other hormone levels (Sharpe et al., 1986; Spencer, 1985.) The effects are on muscle, since glucocorticoids are catabolic to muscle and reduce amino acids and proteins.

In a review by Sharpe et al. (1986) it was suggested that at the physiological level, there is a relationship between growth rate and glucocorticoids; altering glucocorticoid status would increase weight gain.

Glucocorticoids break down muscle proteins for glucose that in turn is used for energy production. This can occur in times of stress, the release of amino acids from muscle proteins to be converted to glucose would decrease the muscle proteins (Desler and Jones, 1995). Androgenic steroids were found to suppress glucocorticoid production in the adrenal glands (Isaacson et al., 1991.) In suppressing this production, the researchers hypothesized that anabolic implant treatment would increase muscle mass.

Mode of Action of Implants

Estrogenic Implants

Estradiol benzoate is an ester of a naturally occurring endogenous estrogen, estradiol 17ß, and is administered in combination with progesterone for use in male animals or with testosterone propionate for use in female animals (Reid, 1983). There have been reports of increased live-weight gain, improved feed conversion and improved growth rate for usage of estradiol benzoate (Reid, 1983).

Estrogens may act directly or indirectly on growth through regulation of plasma growth hormone, insulin and thyroid hormone on growth (Cross and Belk, 1989; Spencer, 1985). Estrogens can directly stimulate cell growth by hypertrophy and inhibit somatomedin production (Spencer, 1985). Estrogens are the original repartitioning agents, since growth is observed by an increase in protein (muscle) with a decrease in fat

deposition (Preston and Herschler, 1992; Reid, 1983). Galbraith and Watson (1978) treated steers with hexoestrol and found the treated steers had significantly higher levels of serum growth hormone than steers implanted with TBA alone or untreated steers.

Estrogen administration decreased dressing percentage, increased ribeye area and muscling, and decreased fat deposition (Prior et al., 1983.) Skeletal muscle contains estradiol receptors with identical properties to estradiol receptors contained in uterine tissue. Meyer and Rapp (1985) indicated that one possible component of the anabolic action of estrogens was from direct stimulation of the muscle through these estradiol receptors.

Estrogens have been administered as ear implants for many years as growth promotants. The estrogenic hormones include estradiol 17ß and estradiol benzoate and the synthetic form, Zeranol. Estrogen anabolics are effective in females, but the greatest response is in castrated male ruminants (Heitzman, 1979). Intact male ruminants have an increase in body fat with estrogen implants (Seideman et al., 1982). McNamara (1986) stated that estrogens alter the adrenergic system so that less fat is released in both bulls and steers, reducing carcass fat. One advantage to estrogen implant usage in bulls has been decreasing the aggressive behavior.

Androgenic Implants

Androgens, including testosterone, have receptors in skeletal muscle (Snochowski et al., 1981; Michel and Baulieu, 1983), indicating the possibility of direct stimulation of the muscle tissue and directly affecting the rate of muscle growth (Roche, 1983).

Androgenic hormones used in implants are testosterone propionate and trenbolone, the synthetic form. Trenbolone acetate (17ß-acetoxy-3-oxoestra-4,9,11-triene), is similar chemically to testosterone and estradiol and binds to both testosterone and estrone skeletal muscle receptors (Anderson, 1991a). Trenbolone acetate (TBA) has 50 times the anabolic potency of testosterone and adds large anabolic advantages in ruminants (Grandadam et al., 1975). TBA is hydrolyzed to trenbolone, which binds to the androgen receptor (Rico and Sacaze, 1984; Jouquey et al., 1983). It was suggested that trenbolone and testosterone reduces the normal catabolic action of glucocorticoids (Buttery et al., 1978; Mayer and Rosen, 1975; Isaacson et al., 1991; 1992). Androgens have a direct mechanism by linking with muscle cell receptor sites and blocking the catabolic effects of glucocorticoids (Hutcheson et al., 1993). One theory was that trenbolone acetate works to alter the glucocorticoid status by exerting action at the corticoid receptor sites in skeletal muscle (Sharpe et al., 1986). TBA reduced the synthesis of serum cortisol, a glucocorticoid, causing a decline in the catabolism of muscle (Isaacson et al., 1992). The researchers suggested that the suppression of cortisol synthesis by TBA would account for improvements in muscle growth of cattle when implanted with TBA. Serum levels of cortisol were also lowered in a study of steers and young bulls implanted with TBA and Zeranol. Jones et al. (1991) concluded that the implants did not alter carcass characteristics, but delayed puberty in bulls. Skeletal muscle that contained androgens and androgen receptors were identified in porcine skeletal muscle. The available free androgen receptors was lowest in hams of fast gaining pigs as compared to slower growing pigs (Snochowski et al., 1981).

Estrogenic and Anabolic Combination Implants

Implants provide a steady, but small amount of additional hormone to the animal during the growth phase, thus the increase of lean muscle growth is at the expense of fat deposition from usage of anabolic implants (Belk et al., 1992). Implanting with an estrogenic implant and an implant of TBA has been found to sustain the levels of estradiol-17ß past the levels of estradiol-17ß when implanted alone (Heitzman and Harwood, 1977, Preston, 1987).

Synovex implants combine estradiol benzoate with either progesterone (steers) or testosterone (heifers). This combination increases growth and protein deposition in cattle and decreases plasma urea and amino acid-N (Preston, 1987). Ralgro and Synovex both redirect nutrients from fat to protein deposition. Steers implanted with either Ralgro or Synovex deposited more protein and less fat at any growth rate. With the increase in rate of growth, the repartitioning of energy from fat growth to protein growth increased as well (Lemieux et al., 1988).

Trenbolone effects on growth rate of both intact males and castrates are small unless combined with estrogenic compounds. There is evidence for an elevated plasma growth hormone concentration when the combination compounds are used (Buttery and Sinnett-Smith, 1984). Trenkle (1990) noted that the male hormone, androgen, alone was not a consistent implant to increase cattle growth until TBA was combined with androgen. Hunt et al. (1991) found that TBA and estradiol combination had the highest serum Growth Hormone and IGF-I and steers had the highest gains from this implant

combination. Estrogens alone or in combination with TBA decreased protein degradation, enhancing protein accretion (Buttery, 1983; Sinnett-Smith et al., 1983). However, in studies with combination of TBA and estradiol, it was indicated that TBA acts by some mechanism other than that of enhancing estradiol that is still not fully understood (Bartle et al., 1988b; Bartle et al., 1990).

Sex Differences with Implants

Heifers/Cows

Research into the effects of implants upon heifers has been limited in the past. An increase in the number of heifers being implanted and fed-out in feedlots continues to increase. A synthetic form of progestin, MGA, melengesterol acetate, has been approved as a feed additive for heifers (Table I). MGA prevents estrogen level fluctuating in intact cycling heifers and is being incorporated with implants during feeding periods (Hutcheson et al., 1993). Hutcheson et al.(1993) continued to recommend androgen as the primary hormone in heifer implants, to have maximum growth, and estrogen as the secondary hormone. Heifers implanted with Synovex had increased live weight gain during the finishing phase, which resulted in a heavier ($P < .05$) hot carcass weight (Goodman et al., 1982). Gill et al. (1987) concluded that TBA + estradiol implanted heifers had the highest gains and the greatest effects of the implant was during the latter period of the trial. A single implant study between Synovex-H, Implus-H and Finaplix-H or a combination of Implus-H and Finaplix-H resulted in heavier carcasses and larger ($P < .05$) ribeye areas

TABLE I

TRADE NAME, HORMONAL COMPONENT, AND DOSE OF GROWTH PROMOTANT APPROVED FOR FEEDLOT CATTLE IN THE U.S.

Trade name	Hormonal component(s)	Dose
Compudose®[a]	Estradiol-17ß	24 mg
Finaplix®-H[b]	Trenbolone acetate	200 mg
Finaplix®-S[b]	Trenbolone acetate	140 mg
Implus®-H[c]	Estradiol benzoate and testosterone propionate	200 mg and 20 mg
Implus®-S[c]	Estradiol benzoate and progesterone	200 mg and 20 mg
Revalor®[b]	Estradiol-17ß and trenbolone acetate	28 mg and 140 mg
MGA®[c]	Melengestrol acetate	.25 to .5 mg/d
Ralgro®[d]	Zeranol	36 mg
Synovex®-H[e]	Testosterone propionate and estradiol benzoate	200 mg and 20 mg
Synovex®-S[e]	Progesterone and estradiol benzoate	200 mg and 20mg

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

than the non-implanted heifers (Eck and Corah, 1993). Similar results were reported by Crouse et al. (1987) in administering immunization against estradiol + TBA and Johnson et al. (1987) for a single implant of Compudose. Compudose also decreased fat thickness ($P < .05$) as well as increasing ($P < .05$) ribeye area 3.6 cm^2 as compared to control heifers (Stobbs et al., 1988).

Increases in hot carcass weight reflect increased ADG and as TBA/E_2 dosage increased, the ribeye area had a linear increase (Bartle et al., 1988b). The researchers adjusting for hot carcass weight, found no differences among the dosage treatments for ribeye area. The highest dosage (200/20) resulted in the largest improvement in ADG and gain efficiency. No other significance ($P > .05$) was noted among treatments in carcass traits for this research.

Synovex-H increased deposition of protein and reduced deposition of fat in heifers (Adams et al., 1990). Galbraith (1980) reported that TBA implanted heifers converted feed more efficiently and had a greater retention of nitrogen, indicating that TBA might have a direct effect on receptors within the tissues of the heifers. Furthermore, the final live weight, carcass weight, and ADG were increased without changing quality and yield grade. Faulkner et al. (1989) implanted Synovex-H on day 1 and 84 and testosterone propionate on day 1 and 84 in both heifers and cows. The testosterone treatment reduced the marbling score ($P < .05$) but, did not alter feedlot performance. This study found testosterone was more effective in heifers than in cows.

In a feeding trial of 20 mg estradiol benzoate and 200 mg testosterone propionate, for a single implant, the implant increased backfat thickness ($P < .1$) and numerical yield grades ($P< .05$). No differences were noted in dressing percentage, kidney-pelvic-heart fat percentage, ribeye area or marbling score (Bartle et al., 1991). Bartle et al. (1992b) concluded that the highest dosage of estradiol and TBA within 1:5 and 1:10 ratios gave the greatest response in heifers.

Cows having advanced age may have a darker colored lean that is objectionable. The lean color, dressing percentage and ribeye area over a 56 day feeding period were found to improve with Finaplix-H and Synovex-H implants on cull cows (Cranwell et al., 1992). The researchers also noted that Synovex-H increased ribeye area when compared to Finaplix-H. Cows implanted with TBA increased the lean proportion of carcasses and had greater live-weight gains than non-implanted cows (Gransworth et al., 1986).

Bulls

Young bulls have been used for meat animals in Europe for many years. With a faster growth rate and leaner, more muscular carcass than steers, bulls would be ideal for today's demand for leaner beef. Maintaining testosterone endogenously does contribute to a leaner, more muscular animal, however, the aggressive nature of penned bulls has made producers reluctant to feed bulls. There is a higher incidence of darker and coarser lean with less palatable cuts from intact males. Therefore, research has dealt with various implant regimes to counter aggressiveness of young bulls. Reduced libido and related masculine behavior were reduced in bulls implanted with Zeranol (Corah et al., 1979; O'Lamhna and Roche, 1984; Chaudhary et al., 1985; Vanderwert et al., 1985b; Fisher et al., 1986). In a similar study, Newman et al. (1990) detected bulls implanted with Zeranol exhibited more head butting and mounting activity at the age of 15 to16 months in comparison to non-implanted bulls. Just prior to slaughter at the age of 13 to 14 months all groups of bulls were mixed with unfamiliar animals. Implanted bulls exhibited head butting to the same extent as non-implanted bulls, but less mounting was observed in the

implanted bulls. The incidence of dark-cutting carcasses was not reduced by the Zeranol implant and tended to increase with slaughter age.

McNamara (1986) reported that using estrogen implants in bulls increased backfat at slaughter from .28 to .36 inches. This concurs with the review by Seideman et al. (1982) that concluded that implanting bulls with estrogenic compounds increased carcass fatness. Synovex-implanted bulls had the greatest ($P < .01$) fat thickness at the 12th rib and the least desirable yield grade as compared to Compudose and Ralgro-implanted bulls (Gordon et al., 1986). Gill et al. (1983) reported bulls implanted with Ralgro had less internal and external carcass fat. Increased external and internal fat and a lower ($P < .01$) yield grade, with a heavier ($P < .05$) carcass composed of a larger ($P < .01$) LD muscle area was reported by Johnson et al. (1982) in Synovex-S implanted, early feedlot Angus bulls. In a similar study with Angus and Gelbvieh cross bulls, the Synovex-H and Synovex-S implant groups were fatter ($P < .01$) than the non-implanted group of bulls. Ralgro-implanted bulls had a more desirable ($P < .01$) USDA yield grade than the Synovex-S implanted bulls. Bulls did not respond to any implant combinations with Synovex and Finaplix in a study by Rouse et al. (1990). Recent research by Shackelford et al. (1992a) implanted intact bulls with Ralgro or Synovex-S. Both implant treatments increased carcass masculinity, but did not differ from non-implanted controls for yield grade characteristics and other carcass traits. Higher ($P < .05$) numerical yield grades were reported for Zeranol or estradiol implanted bulls. Also, the quality grades were higher ($P < .05$) in Zeranol-implanted than control and estradiol-implanted bulls (Calkins

et al., 1986). Calkins and Clanton (1984) observed that implanting intact males with Ralgro® increased carcass fatness and quality grade to the level of the implanted steers.

In a recent study in Canada, bulls had a greater ($P < .05$) carcass weight, dressing percentage, and ribeye area than steers (Cohen et al., 1991). Unruh et al. (1986a) in a study of implanting young bulls with Zeranol on day 1 and reimplanting for an average interval of 84 days until slaughter; concluded that Zeranol implanting from birth to slaughter increased carcass desirability, and delayed masculinity and behavioral development.

One concern for utilizing young bulls for meat has been the darker colored lean as well as the palatability and tenderness of the meat. The palatability of bulls implanted with Ralgro and Synovex-S did not improve among the intact male treatment groups (Shackelford et al., 1992b). Hawkins et al. (1986) found no differences between non-implanted and Ralgro-implanted bulls for panel tenderness, juiciness, flavor, overall satisfaction and Warner-Bratzler (WBS) shear force. No differences between intact males versus late and early castrated steers were discerned in sensory panel evaluations (Vanderwert et al., 1985a). Mean scores for juiciness and flavor were similar between bulls and steers for both non-implanted and implanted. The mean values for tenderness, although not significant, were higher for the steaks from the control bulls than those of implanted bulls (Hawkins et al., 1987).

The decrease ($P < .05$) of dark, coarse band formation of the LD muscle was theorized to be from the increased ($P < .05$) fat thickness and marbling scores of Zeranol-implanted bulls (Unruh et al., 1986b). Price et al. (1983) found a four times greater

incidence of dark-cutting carcasses among control bulls than bulls that were implanted with Zeranol.

Seideman et al. (1985) compared the effects of implanting Synovex or Ralgro on muscle fiber types among steers and bulls. Bulls had a higher percentage of red fibers, large intermediate red fibers and white fibers when compared to the steers. The fiber types for implanted bulls were between that of intact, non-implanted bulls and steers.

Steers

Cattle upon castration lose the natural endogenous androgenic hormones essential for increased skeletal muscle mass and decreased fat as found in intact bulls. With the usage of anabolic implants, the androgenic response will be reintroduced to the steer. Steers have insufficient hormones for maximal growth without the usage of exogenous hormones. (Lee et al., 1990; Roche, 1983). Increased feed efficiencies are an advantage in using anabolic implants without the aggressive nature of intact bulls (Isaacson et al., 1991). Estrogenic hormones were found to increase growth rate but, did not increase fat deposition in steers (Kennett and Siebert, 1987). An increase in IGF-1 concentrations in steers during the growing and finishing phases was noted in steers implanted with TBA (Lee et al., 1990).

Bartle et al. (1990) reported that British crossbred steers reimplanted with TBA on day 70 increased ribeye area ($P < .05$) with a small decrease ($P < .15$) in marbling scores. Bartle et al. (1992b) reported that reimplanting with Synovex plus Finaplix had the highest

steer performance with no differences in marbling score or percentage of Choice carcasses as compared to Synovex alone.

Payout of Combination Implants

Riley and Pope (1984) found that the efficacy of a single Ralgro or Synovex, as measured by an advantage over non-implanted steers, appeared to disappear between day 85 and 112 after implantation. The fastest gaining cattle were groups reimplanted and were most efficient with Synovex on day 75. A single Compudose implant maintained a consistent growth level and efficiency rate during the entire trial.

Maximal response to TBA has been when it was administered with an estrogenic implant used once and administered as a terminal implant (Hickman et al., 1994). The payout from TBA release was evaluated by Hickman et al. (1994). Serum concentrations of TBA were higher ($P < .05$) in steers implanted with Finaplix vs. Revalor for the first 42 to 56 days and then declined. TBA levels were similar for steers implanted with Finaplix or Revalor. The highest level was at 112 days for Revalor. The researchers suggested that shorter feeding periods (less than 120 days) would favor implants that increase anabolic blood levels for the shorter (56 to 64 day) periods.

Nichols et al. (1992) utilized Synovex-S followed by Finaplix-S/Synovex-S; Finaplix-S/Synovex-S followed by Synovex-S; and a Finaplix-S/Synovex-S implant. Steers were implanted on day 0 and the second implant was administered on day 56. All implant treatments equalized by day 154, indicating that the anabolic activity of dual TBA/E improved protein accretion ($P < .05$). The TBA response disappeared in all

categories when TBA was not reimplanted. The researchers stated that TBA needed to be utilized throughout the feeding period or used as a terminal implant.

Rumsey et al. (1992) implanted steers with Synovex-S® on day 0 and reimplanted on day 60. The researchers also administered a single implant on day 0 and day 30 to determine the pattern of implant absorption. The study indicated that greater protein and less fat deposition occurred during the first 38 days after initial implanting and continued through 120 days after the initial implant. Reimplanting steers at the end of 60 days, did not significantly improve production efficiency or improve carcass composition. The response being low was because 25% of the initial implant was still present at day 60. The authors suggested reimplanting might be a benefit after 100 days, but further research was warranted.

Trenkle (1991) in a feeding trial of 116 days with Synovex S and Finaplix-S implants concluded that the two implants when used in combination were effective in increasing growth and profitability of steers, even above that of Synovex-S alone. Feeding steers that were implanted with Synovex and Finaplix on days 1 and 60 required an extra 19 days to improve the carcass grades and increase profits. There was an increase in fat thickness from the additional 19 days of feeding, but there were no yield grade 4 carcasses. The combination implant resulted in the same percentage of Choice carcasses as from steers implanted once or twice with Synovex (Trenkle, 1991).

Reduced marbling scores with the combination of TBA +E_2 were noted when the implants were administered late in the finishing phase (Foutz et al., 1989b; Apple et al., 1990; Trenkle, 1991). Past reports of reduced marbling had increased the practice of

implanting TBA at least 120 days before slaughter to counteract the diminishing marbling scores. No differences in quality grade were reported between steers implanted with a combination of TBA + E_2 and progesterone and the non-combination implants (Hartman et al., 1989; Rouse et al., 1990).

Another method to prevent lower marbling was to keep the animals on feed longer to reach a heavier live weight. Perry et al. (1991) reported the live weight required to reach a small degree of marbling (Choice quality grade) increased 25 to 45 kg with TBA + E2 implants in finishing steers. There was little effect on carcass composition or carcass quality grade within the breeds, Holstein, Angus, and Angus X Simmental. All implant treatments were administered earlier than 120 days before slaughter and resulted in no difference in marbling score or number of Choice carcasses due to the implant treatment of 140 mg TBA and 28 mg estradiol. Wagner and Pritchard (1992) in a feeding trial implanted Synovex-S on day 1 and a combination of Synovex-S and Finaplix-S on day 60. This research revealed lower marbling scores for the implanted cattle. They estimated that 27 additional days on feed would be required for implanted cattle to achieve the marbling scores similar to that of non-implanted cattle. Each day on feed increased hot carcass weight by 1.7 lb. and cattle fed the additional 27 days would be projected to produce carcasses 46 lb heavier at a the similar marbling score.

It has been suggested that the negative effects of TBA on quality grade could be lessened if the combination with estrogenic implants was administered once with 60 to 90 days prior to slaughter (Wagner and Pritchard, 1992; Pritchard et al., 1992). Pritchard et al. (1992) continued to note that in one study there was a 70-day time span from the last

implanting to slaughter and still there was a 10 point decline in percentage Choice carcasses in implanted treatments.

Implant Effects on Slaughter and Carcass Grade Traits

Quantitative Factors

The quantitative factors that are involved in carcass grade traits include external fat (fat opposite the ribeye and over the entire carcass), ribeye area (centimeters squared), internal fat (percentage of kidney, pelvic and heart fat), and hot carcass weight (weight of carcass from the slaughter floor prior to entering the chill cooler). With the current emphasis on leaner beef, many attributes of implants contribute to a leaner, more muscular carcass.

Dressing Percentage

Dressing percentages from cattle implanted with TBA have varied among researchers, the variation appears to be dependent upon the increased live and carcass weight from combination implants. Apple et al. (1991) showed no differences among treatment groups of TBA + estradiol benzoate progesterone (EP), Zeranol (Z), TBA implanted alone, TBA + Z, or TBA + EP. Kercher et al. (1990) noted no ($P < .05$) differences in dressing percentage with Ralgro, Synovex-S, Compudose, Compudose + Finaplix-S, Synovex-S , Finaplix-S and other combinations. Utilizing implants on day 0 and 56 of the trial with the following combinations of TBA+E/TBA+E ; E/TBA+E; and TBA+E/E all had a similar dressing percentage by day 154 of the feeding trial (Nichols et

al., 1992). Heitzman et al. (1981), Keane et al. (1985) and Keane and Drennan (1987) concluded that the dressing percentage of steers with TBA +Z, TBA+EP or TBA +E2 implants were similar to the dressing percentage of untreated steers.

Hot Carcass Weight

Cattle implanted with estradiol plus TBA associated increased rates of gain and produced heavier carcasses as compared to non-implanted cattle fed to the same end time. This would be ideal for smaller framed cattle, but with the large framed steers, there would be discounts with heavier weights (Pritchard et al., 1990). Apple et al. (1991) encountered heavier carcasses from Z, EP and TBA+EP than TBA singularly implanted or C (non-implanted) cattle. Griffiths (1982) noted that TBA+Z implants also produced a heavier carcass than the control group. The implanting of TBA + EP produced heavier carcasses than steers implanted with TBA+Z (Keane and Sherington, 1985). Likewise, Keane (1987) reported heavier carcasses from the TBA+EP treatment than with estradiol-17ß implanted alone and the control steers. There were no differences among TBA+EP, TBA+Z and TBA+E2 treatment groups. Utilizing Synovex-S and Finaplix-S implants, Huck et al. (1991) reported heavier carcass weights from these combination implants. Combining Finaplix and Synovex-S, Huffman et al. (1991) noted carcasses with a greater weight than from either Finaplix, or Synovex-S as single implants.

Kidney, Pelvic and Heart Fat Percentage

With decreased fat deposition in cattle from TBA implants, the effect on the internal fat (kidney, pelvic, and heart fat percentage) is a consideration during evaluation of beef carcasses.

Nichols et al. (1992) upon implanting on day 0 and 56 with TBA+E/TBA+E E/TBA+E, TBA+E/E found similar kidney, pelvic and heart fat percentages by day 154 of the feeding trial regardless of treatment. Keane and Sherington (1985) and Galbraith et al. (1983) found the mean weights of the kidney, pelvic and heart fat to be similar for C and TBA + E_2 and TBA+Z steers. No differences in KPH among implant treatments were noted in implant trials by Kercher et al. (1990); and Apple et al. (1991). Reports of a lower KPH % were noted by Heitzman et al. (1981) and Huffman et al. (1991) in TBA combination implanted cattle. Huffman et al. (1991) also reported the highest kidney, pelvic and heart fat percentage with Finaplix implants.

Fat Thickness

Pritchard et al.(1990) in a study between British and Continental crosses, implanted Hereford X Angus (HA) and Gelbvieh (GX) cross steers with estradiol + TBA and reimplanted on day 77. The HA steers were taken to a slaughter endpoint of yield grade 3.3. It was noted that the GX steers would have been excessively heavy if taken to this yield grade. This study explained larger framed cattle would tend to produce a trimmer carcass of an adequate weight. The GX steers were chosen to be marketed when 0.4 inch rib fat was attained, thus calculating to a yield grade of 2. Implanting these cattle

with TBA + E_2 and reimplanting on day 77, tended to increase ($P < .01$) rib fat thickness (Pritchard et al., 1990).

Increased fat thicknesses were reported by Anderson et al. (1992), in which TBA + E (Finaplix-S and Synovex-S) implanted steers had a greater fat thickness than steers implanted with estradiol alone (Synovex-S). Carcasses from TBA + E_2 implanted steers were fatter than C steers and had a higher subcutaneous to intermuscular fat ratio in research by Wood et al. (1986). Wagner and Pritchard (1992) also found that TBA implanted steers had more ($P < .01$) fat over the 12th rib than the non-implanted steers.

Nichols et al. (1992) administered implants on days 0 and 56 and reported TBA+E/TBA+E and E/TBA+E implants decreased ($P < .05$) backfat of the carcasses. Kuhl et al. (1989) upon reimplanting with S+F, reported a decreased fat thickness, yet there were differences only between the S+F and S treatments. Similar backfat thicknesses were reported by Apple et al. (1991), Galbraith and Watson (1978), Keane (1987) and Kercher et al. (1990) with usage of TBA implants. Rumsey et al. (1992) accounted for a non-significant trend ($P > .10$) for leaner carcasses from steers that were implanted with Synovex-S on day 0, or reimplanted on day 60, or initially implanted on day 30 of the trial.

Ribeye Area

The greatest response to TBA administration has been found in muscle increases and have been well documented by many researchers. Though not significant ($P > .05$), reimplanting with Revalor-S® over three implant periods in a 252 day feeding period

tended to increase ribeye area (Simms and Kuhl, 1993). Kuhl et al. (1989) reimplanting with S+F detected increased ribeye areas, yet no differences between S+F and a single S implant were noted. TBA +Z, TBA+EP and EP implant treatments were similar in ribeye size, however, larger ($P < .05$) ribeyes were found in TBA+EP than Z, TBA and C treatments by Apple et al. (1991).

Cohen and Cooper (1983) found that Zeranol implants increased ribeye area. Rumsey (1992) and Lomas (1983) noted implants of estradiol benzoate progesterone increased ribeye area. Trenkle (1993), Pritchard et al. (1992); Galbraith et al. (1981), Foutz et al. (1989c) and Huck et al. (1991) utilized combinations of estrogenic and androgenic implants with results of larger ($P < .05$) ribeye areas in implants with TBA. A ten percent increase was recorded by Trenkle (1990) with Revalor implants (day 0 and reimplanted on day 80).

The increased ribeye area had been an effect not only from the implant strategy, but also from heavier carcass weights from combinations of estrogenic compounds and TBA (Preston et al., 1992; Eck and Corah 1993a; Huffman et al., 1991). Huffman et al. (1991) reported the increased weight with the larger ribeye area was noted in the Finaplix + Synovex-S implants than in the non-implanted, control steers and Synovex-S implanted steers. TBA implanted steers had larger ($P < .01$) ribeye areas than non-implanted steers in a research by Wagner and Pritchard (1992).

Numerical USDA Yield Grade

As the ribeye area increases in size to proportion of carcass weight and fat thickness opposite the ribeye and internal fat percentage, the USDA yield grade would become favorable for cattle implanted with TBA and estradiol. In a study by Pritchard et al. (1990), carcasses from cattle implanted with TBA + E2 and reimplanted on day 77, yield grade tended to be higher for implanted steers due to the increased ($P < .01$) rib fat thickness. Eck and Corah (1993b) reported increased yield grade in singularly implanted Compudose, Synovex-S, Implus-S steers and singularly implanted Synovex-H, Implus-H, Finaplix-H or IH and FH combination heifers.

Rust and Schlegel (1989) indicated that estradiol benzoate-progesterone implanted on day 0 and TBA implanted on day 75 resulted in lower ($P < .10$) calculated yield grades than cattle implanted with estradiol benzoate-progesterone on day 0 and day 75. Nichols et al. (1992) reported that implanting on day 0 and 56 with TBA-E/TBA-E and E/TBA-E decreased ($P < .05$) yield grades. Apple et al. (1991) found TBA + EP implanted steers to have lower YG scores than EP, Z or C, however all YG were 3.0 or less. Yield grades for Ralgro (2.90) and Ralgro-Synovex-S (2.87) reimplanted on day 69 on a 160 day trial were lower ($P < .05$) than Controls (3.10) in a research by Combs and Hinman (1984).

Qualitative Factors

Qualitative factors that affect the quality of beef carcasses include marbling score, as well as lean color maturity, skeletal maturity and the overall maturity.

Lean Maturity/Color

Lean color can vary from a typical cherry-red color of beef to a darker red to a blackish-red color indicative of "dark cutters". The usage of implants containing TBA with certain cattle types and environment are charged as a causative agent in dark cutters by some meat packers (NCA, 1993). Research conducted has not documented dark-cutting beef for implant usage (Hoechst-Roussel, 1995). Brethour (1985) reported that steers implanted with TBA + EP produced some dark-cutting carcasses, but attributed these to the extended time between arrival and slaughter.

Dark Cutters. Dark-cutting beef is a condition when muscle glycogen stores are depleted prior to slaughter. This depletion can be accelerated by stress to the animal. During stress, glycogen will be metabolized through the anaerobic pathway and form lactic acid as a by-product. The muscle pH will not go through a normal decline, but remains at 6.0 or higher. From a higher pH the water holding capacity of the muscle will be high and the surface of the lean reduces light reflectance and forms an oxygen barrier, preventing formation of a typical bright cherry red color of fresh beef. This condition is termed dark, firm and dry or commonly called dark-cutting beef.

Stresses that can induce dark cutting beef include penning unfamiliar cattle together before slaughter (Bartos et al., 1993; Price and Tennessen, 1981), and to fluctuating ambient temperatures, rough handling and even implants (Grandin, 1992). This incidence is a result of antemortem depletion of glycogen stores in the muscle due to the various stresses. The control of antemortem stress was found to be of importance in

eliminating dark cutters and genetic variations were minimal (Shackelford et al., 1994c). Dark cutting beef has cost the industry $5.00 for every fed steer/heifer and affects up to 5% of fed cattle in the U.S. according to the 1991 National Beef Quality Audit.; this is an increase from a reported 0.5% in 1975 by Epley (1978). Approximately 5% of all carcasses were dark cutters in the National Beef Quality Audit in a survey of 28 packing plants as reported by Lorenzen et al. (1993). This included cattle that had any reduction in USDA quality grade, due to the darker color and within this category, .1, 2.1, and 1.6% of the carcasses that would have graded Prime, Choice, or Select, were reduced to the next lower quality grade. The incidence was noted to be 4.7% for steers and 5.6% for heifers. The incidence for native, *Bos indicus*, and dairy cattle was 4.7, 4.4, and 9.7%, respectively in this regional survey (Lorenzen et al., 1993).

Apple et al. (1991) and Foutz (1990) reported that steer carcasses implanted with trenbolone acetate were darker in color than carcasses with other implant treatments. Steers reimplanted on day 57 with TBA + E_2 had a high incidence (16.7%) of dark cutters; Brandt and Dikeman (1993) concluded that implanting steers with less than 68 days on feed prior to slaughter may increase dark cutting carcasses. In an implant study with Synovex-S and Finaplix-S implants did not produce any dark cutters in high-concentrate feeding trials to a subcutaneous fat thickness of .35 or .55 inches (Huffman et al., 1991). In a review by Bouffault and Willemart (1983) the influence of TBA alone or in association with estrogen was reported not to change the color of meat in either veal calves or in adult cattle.

Masculinity

Steers implanted with trenbolone acetate and estrogen have been reported to exhibit a staggy or a more masculine carcass (Galbraith and Watson, 1978). This appearance would depend on the implanting schedule in steers when TBA and an estrogenic implant are used. Stagginess in heifers has been reported in heifers more than steers when implanted with high levels of androgen (Hutcheson et al., 1993). Foutz et al. (1990) observed that carcass masculinity was slightly increased for late and double implanted TBA steers.

Busby and Loy (1991) reported significant ($P < .05$) differences in masculinity scores for F+S treatments than controls on day 35 and 70, but all treatments were the same on day 139. Steers implanted with 140 mg TBA and 20 mg estradiol benzoate + 200 mg of progesterone were more ($P < .05$) masculine than steers implanted with only estrogenic implants and non-implanted controls (Apple et al., 1991). However, in this study, the average masculinity score of the TBA + EP treatment was 2.1 (slightly masculine).

Skeletal Maturity

Reports of increased skeletal maturity have been attributed to single implants of TBA and estrogenic compounds. Greathouse et al. (1983) reported increased skeletal maturity from Zeranol-treated bulls even when slaughtered at a younger chronological age than the control (non-implanted) bulls. In a more recent study, an increased skeletal maturity was noted by Apple et al. (1991) in TBA+EP, TBA+Z and EP implanted steer

carcasses. The TBA implanted steers had younger skeletal maturity than the other implanted steers and all were within the "A" maturity.

Overall Maturity

Vanderwert et al. (1984) and Prichard et al. (1984) reported Zeranol implants increased the overall carcass maturity over control cattle. Zeranol had greater negative effects on maturity among steers than among bulls in the Vanderwert et al. (1985b) study. Greathouse et al. (1983) increased overall maturity from Zeranol treated bulls. Overall maturity was unaffected in bulls implanted with anabolic agents (Johnson et al., 1986).

Marbling

Pritchard et al. (1990) noted that implanting cattle with TBA plus estradiol affected intramuscular fat to a greater extent than subcutaneous fat deposition. When carcass data was adjusted to a constant rib fat thickness by covariate analysis, differences in carcass weight and quality grade continued due to implant treatment. Though not significant ($P > .05$), reimplanting with Revalor-S® over three implant periods in a 252 day feeding period tended to reduce marbling without influencing other carcass characteristics (Simms and Kuhl, 1993). Kuhl et al. (1993a; 1993b) in a study utilizing Synovex-S and Revalor found marbling scores slightly lower for Revalor treatments.

A larger percentage of carcasses grading low Choice (75%) with a higher quality grade and better marbling score was noted in the control, non-implanted steers than those implanted with TBA by Busby and Loy (1991).

Nichols et al. (1992) with TBA-E/TBA-E E/TBA-E, TBA-E/E implanted on day 0 and 56, found similar marbling scores by day 154 of the feeding trial. The Holstein study by Apple et al. (1991) had mean marbling scores that were not affected by implant treatments. Kercher et al. (1990) noted no ($P > .05$) differences in marbling with reimplantation of Finaplix-S after initial implanting with Compudose and Synovex-S or 36 mg Ralgro.

USDA Quality Grade

Trenkle (1993) in a urea feeding trial with Synovex and Finaplix administrered at the beginning of 107 days reported that implants decreased the percentage of Choice carcasses. However, the implants did not affect the quality grade of cattle fed high concentrations of protein. The percentage of Choice carcasses were reduced by implanting with estradiol + TBA and reimplanted on day 77, when cattle were fed to a 0.6 inch rib fat (Pritchard et al., 1990). Fifty percent of TBA + EP treated steers graded low Choice or higher. Of the other treatment groups, 100 % graded low Choice within the control group, 75 % in TBA implanted group, 82 % for Zeranol implanted, 90 % for EP single implant and 83 % for TBA + Z Holstein steer carcasses (Apple et al. 1991).

Anderson et al. (1992) confirmed that TBA + E decreased the percentage of Choice cattle. In a study with a dietary supplement of fishmeal, the percentage of Choice increased from 52 to 68. Nonetheless, the percentage of Choice in Limousin carcasses was reduced ($P < .05$) with TBA implants. (Botts, 1992). Hartman (1989) reported that a reduction in marbling scores with TBA implants (EP or TBA + EP) in turn, reduced the

percentage of carcasses grading low Choice or higher, than carcasses implanted with Z or TBA+Z. In contrast, Brethour (1985) found marbling score and quality grade to be lowered when steers were implanted with TBA + Zeranol, as well as TBA + EP.

Fox et al. (1989) in a study with Revalor (140 mg TBA + 29 mg E2) found no differences between breeds (Angus, Holstein or Simmental X Angus) and implant treatment on quality grade, with an average of low Choice. Kuhl et al. (1993b) in a study with Synovex-S and Revalor implant treatments, found no differences in the percentage of steers grading USDA Choice by type of implant. Within another reimplanting trial combining Synovex + Finaplix, Kuhl et al. (1989) noted reduced marbling scores and the percentage of Choice, yet there were differences between Synovex + Finaplix and Synovex alone.

Quality grades of carcasses were not changed by either a single, initial Revalor or Synovex-Finaplix as a reimplant (Trenkle, 1990). Reimplanting with Revalor and Synovex resulted in 47 percent of cattle grading Choice as compared with 78 percent of the cattle grading Choice on other treatments. A reduction in quality grades was noted in studies in which TBA was used in combination with estrogen during the entire finishing period. More energy was being used for growth of muscle and less was available for fat deposition in the form of marbling.

Warner-Bratzler Shear Values

Warner-Bratzler shear (WBS) values have been a standard for determining the tenderness of cooked beef. Research has been limited in examining the impact of implant

compounds and the possible effect on WBS values. A review by Belk et al. (1989) evaluated various TBA implant feeding trials. The reviewers found no effect on Warner-Bratzler shear force values ($P > .05$) among treatments of TBA and feeding trials. Likewise, researchers, Hunt et al. (1991) found no differences in shear force among steers implanted with TBA + E_2 and non-implanted steers.

Trenkle (1990) reported shear force values between all treatments were not significant. Treatments included Synovex S on day 0 and reimplanted on day 80, Synovex-S /Finaplix-S (Synovex S on day 0 and reimplanted Synovex-S and Finaplix S on day 80), and Revalor S (day 0 and reimplanted on day 80). Apple et al. (1991) reported shear values among all treatment groups were similar ($P > .05$). The sensory panel scores for overall tenderness tended to be lower for steaks from steers implanted with EP and TBA + Z than for Z and C steers.

There was a slight tendency ($P = 0.18$) for steaks from Finaplix and Finaplix + Synovex steers to have higher (less tender) WBS values from steaks that were aged for 5 days (Huffman et al., 1991). WBS shear force was similar among treatments with Synovex-S and Revalor implants in a study of heavy weight Holstein steers utilizing two levels of estradiol plus TBA (140 vs. 120 mg of estradiol) in a study by Kuhl et al. (1993a; 1993b). Nute and Dransfield (1984) found no differences in shear force toughness values, which corresponded to the sensory panel tenderness scores, of from sirloin samples from Zeranol implanted and non-implanted steers.

Cooking Losses

Subsequently, TBA + estrogenic implant effects of increasing leanness and decreasing intramuscular fat, a higher percentage of moisture would be realized, thus increasing cooking losses could occur. There was a significant effect on percentage cooking loss ($P < .05$) reported from TBA implanted cattle in the review by Belk et al. (1989). An earlier study by Borger et al. (1973b) reported a greater ($P < .05$) cooking loss that was significant between steaks from Zeranol-implanted and control cattle.

Roasts from Holstein steers that received implants of diethylstilbestrol (36 mg) and progesterone (200 mg) and estradiol-17ß-benzoate (20 mg) were reported to have a significantly lower percentage of total loss and drip loss and were found to be less tender (Forrest and Sather, 1964). Nute and Dransfield (1984) found no differences in cooking losses from 3 kg sirloins removed from Zeranol implanted steers and control, non-implanted steers.

Proximate Analysis

Borger et al. (1973a) reported a significantly ($P < .05$) increased water percentage and a decreased lipid percentage in the ribeye from steers implanted with 36 mg Zeranol implanted steers on day 1 and 84. There were no differences between treatments in protein percentage, or soluble collagen percentage between Synovex-S and Finaplix-S implanted cattle (Huck et al., 1991). Similarly, Nute and Dransfield (1984) found no differences in protein, collagen or myoglobin contents in sirloins from Zeranol implanted steers.

Ether Extracts

Rouse et al. (1990) found no significance differences in ether extract values in combination implants of androgen and synthetic estrogen for steers or bulls. Similarly, there were no differences in ether extract percentage between Synovex-S and Finaplix-S treatments (Huck et al., 1991). Lipid concentration ranged from 1.3 to 3.3 percentage for control and 1.2 to 3.1 percentage for sirloins obtained from Zeranol implanted steers. There was no difference ($P > .05$) between the control and Zeranol implanted cattle (Nute and Dransfield, 1984).

Tenderness and Palatability

Palatability factors vary among individuals and factors such as meat color, flavor, aroma, tenderness and method of cookery all are involved in meat "taste", and consumer acceptance. Tenderness is the major palatability factor that affects consumer acceptance of beef (Morgan et al., 1991). Tenderness differences occur between carcasses, between muscles within the same carcass, and between regions of the same muscle as reported by Shackelford et al. (1990). The authors also reported the window of acceptability requires Warner-Bratzler shear values to be below 4.5 kg for consumers to identify beef as tender. There have been reports that anabolic implants influence the tenderness of beef, however, as stated above, few studies have examined the effect of TBA upon tenderness.

Postmortem Aging

Postmortem aging is one of the most widely used tenderizing process in the beef industry. Jeremiah and Martin (1978) reported that postmortem storage at 0 to 5° C improves meat tenderness. Conventional aging included holding meat between 0 to 4° C for various time periods from 3 days up to 3 or 4 weeks. Beef carcasses were initially cooler aged before shipping intact prior to the "boxed" beef move within the industry. Currently, the fabrication of beef carcasses into primal and subprimal cuts has changed the marketing of beef products. Beef is cut and vacuum packaged, boxed and then stored in cooler temperatures until marketed to wholesale or retail outlets. Vacuum packaging enhances palatability by presenting a controlled aging atmosphere through packaging (Seideman and Durland, 1983). The marketing method of the beef product determines the length of time that the meat will be aged (Minks and Stringer, 1972). In an early study, Martin et al. (1971) stated that a cooler aging of 6 days for young carcasses of all sizes, sexes, and degrees of fatness was sufficient to produce a consumer product of satisfactory tenderness. Hodges et al. (1974) reported that optimum tenderness was attained after approximately 15 days postmortem under vacuumed storage.

Muscle response to aging varied among antemortem factors of age, sex, breed, level of nutrition, stress, exercise and postmortem factors of chilling temperature, duration of aging, cookery heat method, method of cooking. Koohmaraie (1994) concluded that changes occurring within the skeletal muscle result in the loss of tissue integrity and is important in improving meat tenderness. Included in these changes are Z-disk weakening

or fragmentation of myofibrils, degradation of titin, which connects myosin filaments, degradation of nebulin (I-band), and disappearance of troponin-T. However, the post-mortem proteolysis was reported to be most important in affecting meat tenderness. Locker et al. (1977) noted that the basic process of aging was an attack by 'calcium-activated factor' (CAF) on the integrity of the gap filaments within the sarcomere.

In the National Beef Tenderness Survey, Morgan et al. (1991) indicated that the average aging time nationwide for all beef cuts was evaluated to be 17 days with a range from 3 to 90 days. Davey and Gilbert (1969) and Minks and Stringer (1972) reported the correlation between increased tenderness and aging. Decreased moisture loss and microbial growth had been shown in aging beef in vacuum by Minks and Stringer (1972). Most meat was determined to be more tender after a 7 to 10 day postmortem aging period than the day after slaughter (Smith et al., 1978).

Davis et al. (1975) found that aging improved tenderness ($P < .05$) as determined by sensory panel ratings for loin steaks aged 12 and 16 days when compared to steaks aged 4 days. Warner-Bratzler shear values were lower ($P < .01$) for steaks aged 12 and 16 days when compared to steaks aged 4 days. No differences in tenderness between steaks aged 12 and 15 days were detected by either the shear test or sensory panel. Tenderness increased rapidly when meat was aged up to 7 to 9 days and prolonged aging past 17 days resulted in minimal improvement of tenderness. Beef ribeyes had the greatest decline in shear force by 14 day of aging (Koohmaraie et al., 1988a, 1991). Smith et al. (1978) reported that aging of U.S. Choice beef carcasses for 11 days optimized the tenderness of muscles for major cuts of the carcass. This increased tenderness has been

associated with proteolysis of myofibrillar proteins during increased post-mortem storage. Culp et al. (1973) concluded that shear force values were lower for the longissimus dorsi after 28 days of aging, however tenderness did not improve beyond 8 days of aging for other muscles. Mitchell et al. (1991) evaluated the shear force values of the *Longissimus dorsi* and found the steaks to be significantly more tender when aged 10 or 21 days as compared to steaks aged for 3 days. The workers concluded that there was little advantage in extending the aging period of the *Longissimus dorsi* and *Semimembranosus* steaks beyond 10 days of aging.

In a comparison of 7 and 15 day aging period, Minks and Stringer (1972) indicated 15 day aging significantly ($P < .01$) decreased Warner-Bratzler shear values of beef loin and rib steaks. Jones et al. (1991) reported increased tenderness and overall palatability of rib-eye steaks with increased postmortem aging. As aging significantly ($P < .05$) increased from 4 to 11 days, the unacceptable ratings of steaks decreased from 38.8% to 24.0%, respectively. Olson et al. (1977) found a progressive decrease in shear values in ribeyes. In an earlier work, Olson et al. (1976) reported decreases in *Longissimus dorsi* shear values over aging period. The shear values of *Longissimus dorsi* increased in tenderness from 2 to 21 days of aging (Field et al. 1971, Jennings 1978). Field et al. (1971) found that the *Longissimus dorsi* had a greater aging response than the *Biceps femoris,* similar to Semiek and Riley's (1974) study.

Parrish (1969) did not find significant aging effects on shear force values of USDA Choice *Longissimus dorsi* or *Semimembranosus* steaks. Top loin steaks were significantly ($P < .05$) more tender after 20 days aging then steaks aged for 13 days, whether chilled or

frozen. Wheeler et al. (1990a) reported greater improvement in tenderness from 7 to 14 day postmortem aging of ribeyes and 7 day aging were the least ($P<.05$) tender.

Proteolytic Enzymes

Proteolytic enzymes altering myofibrillar proteins have been reported by Locker, 1960; Parrish, 1973; Goll, 1974; Dutson, 1983; Goll et al., 1983 and Tarrant, 1987. Proteolytic degradation of muscle proteins occurs during postmortem aging (Asghar and Bhatti, 1987).

Calcium Dependent Proteases

Ca^{++} dependent proteases are found in skeletal muscles and have been shown to degrade myofibrillar proteins. Ca^{++} dependent proteases play a major role during post-mortem tenderization of meat. During rigor mortis, the calcium is released from the sarcoplasmic reticulum. The lysosomal enzymes (primarily cathepsins) also influence tenderness. The cathepsins require an acidic pH for activity (Marsh, 1983). Calcium-dependent proteases (CDP) and certain cathepsins degrade myofibrillar proteins. Individual CDPs, individual cathepsins, or the synergistic action of the two have been identified as being responsible for the postmortem changes leading to meat tenderization (Dutson 1985; Pearson et al., 1983; Koohmaraie, 1988b). Two forms of CDP, (CDP-I and CDP-II) were identified as the CDP-I requiring low Ca^{++} and CDP-II requiring high Ca^{++}. Ca^{++} dependent proteases and protease inhibitors were further examined by Koohmaraie et al. (1987). The researchers noted that CDP-II remained constant

throughout postmortem storage; however, a progressive decrease in the activities of low Ca^{++}-requiring calcium-dependent protease (CDP-I) and their inhibitors was exhibited. This inhibitor was found to be susceptible during post-mortem storage. Koohmaraie et al. (1987) concluded that improvement in tenderness during storage was from changes in the myofibrils and CDP-I is important in the fragmentation of myofibrils. Ca-dependent proteases (CDP) require Ca and have a neutral pH optimum for activity. Shackelford et al. (1991a) determined that increased CDP inhibitor activity increased toughness in carcasses that were at least 5/8 Brahman. Whipple et al. (1990a) reported a strong positive correlation for inhibitor activity at 24 hour postmortem and 44% of the variation in Warner-Bratzler shear force was explained by calpastatin activity at day 1. This activity at day 1 was significantly related to the tenderness within the longissimus muscle.

Calkins and Seideman (1988) cited calcium-dependent proteases (CDP-I and CDP-II) and cathepsins activity during the aging process. Calcium-dependent proteases establish initial tenderness within 2 days. Koohmaraie et al. (1988a) found the longissimus muscle to have high CDP-I activity and aging response, whereas, the psoas major had low CDP-I activity and aging response.

Eilers et al. (1994) concluded within aging times of 6, 12, 18 or 24 days, that electrical stimulation improved the tenderness of strip loin steaks. However, the tenderness of the strip loin was improved by postmortem aging periods of 12 days or longer. The frequency of strip loin steaks with "unacceptable" (3.9 kg or higher) shear force values was reduced by aging the strip loins for at least 12 days. Therefore, the researchers suggest that strip loins should be aged for at least 12 days to ensure

"acceptable" tenderness, then aging periods of up to 24 days may be beneficial. The 24 day aging periods resulted in strip loin steaks with the lowest mean shear force values and the highest meat tenderness ratings and 70% of the steaks had shear force values below 3.2 kg.

Cathepsins

Cathepsin B is a lysosomal protease that degrades myosin, troponin T and actin. Endogenous inhibitors (calpastatin or CDP inhibitor) block the activity of both CDP-I and CDP-II (Koohmaraie, 1988b). Proteases and inhibitors are located in the cytosol of the muscle cell and at the Z-disks where most changes occur in the muscle during postmortem storage (Dayton and Schollmeyer, 1981) Cathepsins B, H and L are found within the lysosome of the skeletal muscle.

Calkins et al. (1987) indicated that CDP-I plays an important role in determining the initial tenderness of muscle and that cathepsin ß is related to the extent to which tenderness may be enhanced during aging. The researchers aged longissimus muscles for 1, 6 and 14 days and the activity of cathepsin B, cathepsin H and ß-glucuronidase were determined within 1 hour of death in samples from 3 bull and 4 steer carcasses. CDP-I was correlated ($P < .1$) with shear force at day 1 and day 14. Cathepsin ß was correlated with the change in shear force between day 1 and day 12 ($P < .05$). Partitioning of the aging response between day 1 to 3, when 39.5% of the improvement in shear force occurred, and day 3 to 14 revealed that cathepsin ß was primarily related to aging during the latter phase ($P < .05$).

Most of the aging response occurred between day 3 and day 6 (41.6%), and changes in shear force during this period were related to total activities of cathepsins B and H ($P < .05$). Cathepsins B and H accounted for 35 and 58% of the variation in shear force change between day 1 to day 14 and day 3 to day 6, respectively. CDP-I helps to establish initial (d 1) meat tenderness but that cathepsins B and H are responsible for the tenderization that occurs during aging (Calkins and Seideman, 1988).

Recently, Koohmaraie (1994) has concluded that lysosomal cathepsins do not play a significant role in postmortem proteolysis. Multicatalytic proteinase complex (MCP) was also concluded to have no effect upon myofibrils and plays no role in postmortem proteolysis to result in meat tenderization (Koohmaraie, 1994), suggesting that calpains are the primary proteolytic system responsible for meat tenderization during post mortem proteolysis. Koohmaraie (1990) reported cathepsins B and H influence the tenderization of beef over a long period of time. Differences in the aging response of muscles could be attributed to the activities of calcium-dependent proteases (CDPs).

Cathepsin B + L (acidic proteases) enzyme activity and neutral calcium-dependent proteases (CDP) may influence the postmortem tenderization process. Research to determine tenderness differences among breeds has become more prevalent. Steaks from Angus and Angus X steers were aged 1, 5 and 10 day postmortem aging. Shear force values at day 1 had no differences among breed types, however by day 10 of aging, the Warner-Bratzler shear values were lower ($P < .05$) from Angus steers (Johnson et al. 1990). Breed type did not alter the level of CDP activity; Warner-Bratzler shear and cathepsin B + L total activity differed among breed types. The amount of cathepsin B + L

activity increased as the percentage of Angus breeding increased in carcasses in a study comparing Angus breeding and tenderness. This research indicated that there are breed differences that affect tenderness. Cathepsin B + L activity was negatively related to WBS at day 10. Johnson et al. (1990) suggested that the differences in meat tenderness among breed types may be from the differences in proteolytic enzyme activity. In a similar study between Brahman and Hereford cattle, Wheeler et al. (1990b) concluded that calcium-dependent protease activity, modulated by calcium-dependent protease inhibitor played a major role in the tenderness differences between the two breeds. Also, there was no myofibrillar response and activities of cathepsin B or cathepsin B + L were not different between the breeds. Koohmaraie et al. (1988 a, b) found no differences in catheptic enzyme activity and tenderness. The researchers continued to conclude that postmortem changes during storage were associated with CDP activity.

Muscle Fiber Size

Crouse et al. (1991) reported that muscle fibre size is important to tenderness prior to postmortem storage of meat and proteolysis, but becomes less of a factor in tenderness after 6 days of storage. Average muscle fiber size was correlated ($P < .01$) with tenderness and shear force values at days 1 and 3 of postmortem aging, but not at days 6 and 14.

AgingTreatment and Implant Effects

Vanderwert et al. (1986) utilized Zeranol implants in Angus and Limousin bulls and steers. The WBS determination on the longissimus muscle indicated that breed was the most consistent main effect difference, with Angus cattle having lower WBS values than Limousin. Control (non-implanted) steers had significantly lower Warner-Bratzler shear values than rib steaks from steers implanted with Zeranol each 84 day interval while on feed (Hawkins et al., 1987).

Various researchers noted similarities in Warner-Bratzler shear values among implant treatments with a zero day aging period for longissimus muscle samples Deans et al., 1956; Forrest, 1975; Forrest and Sather, 1965; Gregory et al., 1983; Hawkins et al., 1986; Huck et al., 1991; Hunt et al., 1991; Kuhl et al., 1993b). During a 6 day aging period, Holstein steer longissimus muscles were similar in WBS for treatments of TBA, TBA+ estradiol and Zeranol implants. There were no effects in shear values after a 4 day aging period for Revalor and Synovex implant treatments. This study evaluated Hereford, Hereford x Angus and Charolais bulls and there was no effect among the breed groups in the shear values (Johnson et al., 1984). A 5 day aging period for steaks removed from Angus steers implanted with either Finaplix, Synovex-S, or Finaplix and Synovex-S resulted in a tendency ($P = .18$) for the WBS shears to be higher (less tender) within the Finaplix and Finaplix + Synovex-S implant treatments.

Increasing the aging time to 7 days with implant treatments resulted in various effects upon the Warner-Bratzler shear values among breed and gender groups. Utilizing the longissimus muscle of Charolais x steers, Trenkle (1990) noted no effects upon the

shear values among implanting and reimplanting (80 d) with Revalor or Finaplix-S + Synovex-S Crouse et al. (1987) evaluated heifers with TBA and immunized against estradiol; after 7 day aging of longissimus steaks all shear values were similar among the treatment groups.

Studies have been conducted addressing meat palatability traits between young bulls and steers with similar implanting treatments. Vanderwert et al. (1985a) evaluated intact and late castrated Angus males, the shear values from the steer longissimus muscle was lower than for the intact males. The lower shear value was noted after a 7 day aging period for the steaks. Various Zeranol implant periods were examined for bulls and castrated calves (Simmental cross), the longissimus steaks were more tender ($P < .05$) from the steers than from all bull groups (Unruh et al., 1987). The researchers also reported that bulls implanted from birth to slaughter were more tender ($P < .05$) than the other implant treatments. This implanting group was reaching the palatability level of implanted steers. Carcasses from cross-bred bulls and steers were aged for 144 h and at 192 h (8 d) longissimus steaks were removed for cooking and shearing (Jones et al., 1986). The research workers detected no treatment differences were noted, but the comparisons between steers and bulls approached significance ($P < .06$) in shear values. Tenderness improved ($P > .05$) regardless of implant after a 7 day aging period for steaks removed from Angus bulls implanted with Zeranol and combination of estradiol-17ß and Zeranol (Smith et al., 1989).

Calkins et al. (1986) evaluated intact males and steers from Angus x Hereford dams and MARC II sires (one-fourth each of Angus, Gelbvieh, Hereford and Simmental)

implanted with Zeranol and estradiol-17ß. The wholesale ribs were aged for 10 days and steaks were removed for shear analyses. The shears from the Zeranol-implanted steers were less tender ($P < .05$) than from the control steers. Direct comparisons between intact males and steers were not different ($P > .05$) (Calkins et al., 1986). In another study, Simmental bulls and steers were implanted with estradiol-17ß (Hopkins and Dikeman, 1987). The workers aged *Longissimus dorsi* muscles for 10 days and reported lower ($P < .05$) shear force values for implanted steers than for implanted and non-implanted (control) bulls.

Responses to shear values were noted to be gender dependent with Synovex-S implants and reimplants (100 d) of Angus bulls and castrated males in a study by Johnson et al. (1982). The bull longissimus steaks had higher ($P < .01$) shear values than the steers, even after a 14 d aging period. Core samples from Angus bullock rib steaks required less ($P < .01$) shear force than samples from Gelbvieh crossbred rib steaks after 10 days of aging (Johnson et al., 1986).

Steers had lower ($P < .05$) WBS shear values than intact males from Angus, Simmental x Hereford and Simmental breeding when implanted with Ralgro and Synovex-S (Shackelford et al., 1992b). The researchers aged the *Longissimus dorsi* steaks for 5, 10 and 15 days postmortem prior to cooking and shearing. The Ralgro-implanted bulls had higher WBS shears than the non-implanted bulls, while the Synovex-S implanted bulls had the lowest score for overall tenderness The slaughter endpoint and postmortem aging period affected WBS values. The response to aging was the greatest for the first slaughter group (190 d) and was the least for the last slaughter group (315 d). Across the breed

types, Simmental had the greatest (less tender) WBS shear values, Simmental-Hereford was intermediate, and Angus had the lowest (most tender) WBS shear values (Shackelford et al., 1992b). In a study using six sets of purebred Brangus clones (Hermel, 1994), there were no differences in shear force values among the treatment groups.

Breed Types and Tenderness

In an early study by Jeremiah and Martin (1977), the researchers evaluated the differences between Charolais, Chianina and Simmental sired bulls, steers and heifers. Utilizing Zeranol implants in Limousin versus Angus, Vanderwert et al. (1989) noted Angus cattle had longer sarcomere lengths and were more tender ($P < .01$) than Limousin.

In a study of Brahman cross cattle, 1/4 Angus x 3/4 Brahman cross had higher ($P < .05$) Warner-Bratzler shear values (3.94 kg) as compared to Angus (3.45 kg) and 3/4 Angus and 1/4 Brahman (3.36 kg) (Williams et al., 1987). Crouse et al. (1989) reported that as the percentage of *Bos indicus* inheritance increased, within-breed-group variation in shear values increased ($P < .05$). The researchers also reported *Bos indicus* were more ($P < .05$) variable in tenderness than the *Bos taurus* breed crosses and Pinzgauer breeding had greater ($P < .05$) shear values than those for the Hereford-Angus-cross group. This research indicated that the tenderness was probably related to the fragmentation of the myofibril component in the muscle (Crouse et al., 1989). The decreased tenderness in *Bos indicus* crosses was reported to be related to increased calpastatin activity at 24 hour postmortem (Whipple et al., 1990b; Shackelford et al., 1991c). Gelbvieh crosses had numerically ($P< .05$) lower calpastain activity and Warner-Bratzler shears than Nellore

crosses, which were also found to be tough and to have a high calpastain activity at 24 hours postmortem (Shackelford et al., 1994b).

Late maturing (Chianina) and early maturing (Hereford x Angus) cattle were evaluated on tenderness of the longissimus muscle. As the days of grain feeding increased, from day 0 to day 77, the shear values increased (decreased tenderness) and remained fairly constant until day 182 of feeding (Wheeler et al., 1989). Whipple et al. (1990b) noted shear-force values were lower ($P < .05$) in steaks from Hereford x Angus crosses at 1 and 14 day postmortem than steaks from 3/8 and 5/8 Sahiwal x Angus x Hereford (SAH) crosses. However, calcium-dependent protease inhibitor total activity was greater ($P < .01$) at 24 hour postmortem for 5/8 SAH and 3/8 SAH than for Hereford x Angus. In a similar study, Van Vleck et al. (1992) reported that six Sahiwal sires ranked in the highest six places for shear force as compared to Angus sires which ranked the lowest for shear force estimated breeding value.

CHAPTER III

EFFECTS OF COMBINATION ANDROGENIC AND ESTROGENIC ANABOLIC IMPLANTS ON CARCASS TRAITS OF SERIALLY-SLAUGHTERED STEERS

Abstract

Yearling steers from a similar background (n = 514) were fed a high concentrate diet and serially-slaughtered after 127, 148 or 169 days on feed to evaluate the effects of an androgenic implant, trenbolone acetate (TBA), in combination with estradiol benzoate on carcass grade traits. Implant treatments were: CON = non-implanted control, ET = 28 mg estradiol benzoate plus 200 mg TBA on day 0, ETET = ET administered on day 0 and reimplanted on day 61, and SET = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 with a reimplant of ET on day 61. Steers were slaughtered and carcass grade traits were evaluated at approximately 66 hours postmortem. Implant treatment least squares means were compared at four constant endpoints: time-on-feed (148 days), slaughter weight (457 kg), subcutaneous fat thickness (1.53 cm), and marbling score (Small ^{59}). Implanted steers were heavier ($P < .05$) (slaughter and carcass weights), more advanced ($P < .05$) in skeletal and overall maturity, similar in lean color and fat thickness, and possessed larger ($P < .05$) ribeyes than CON steers. Of the 514 steers slaughtered, no

dark cutters were detected. The use of a combination estrogenic and androgenic implant resulted in lower ($P < .05$) marbling scores and fewer U.S. Choice carcasses than controls. Under the conditions of this study, implanted steers required an additional 35 to 44 days of high concentrate feeding to achieve a similar degree of marbling to non-implanted controls.

(Key Words: Beef, Anabolic Implants, Carcass Traits, TBA)

Introduction

Anabolic implants have been used in feedlots to improve growth and feed efficiency. Trenbolone acetate (TBA), an androgenic compound, has an additive effect with estradiol benzoate (EB) to increase feedlot performance, muscling and leanness. Because combination implants (TBA and EB) have been profitable, usage by feedlot operators has increased.

On the negative side, the percentage of feedlot cattle implanted with TBA grading U.S. Choice or above is as low as 40% compared to 70 to 80% for other implants (Anderson, 1991b). In comparing three weight endpoints, Anderson et al. (1991b) noted that increasing days fed or the live weight at slaughter for TBA+EB implanted steers would reduce differences in marbling without the loss of other TBA+EB induced carcass size and muscularity advantages. Various reimplant studies have been conducted to determine if reimplantation during the finishing phase would optimize muscle growth and feeding efficiency. Reimplantation with EB plus TBA has improved steer performance with no depression in marbling score or percentage of U.S. Choice as compared to EB

alone (Bartle et al., 1992b). Hence, numerous researchers have suggested that an implant window exists in which reimplant time prior to slaughter must be considered to balance performance, carcass cutability, and carcass quality.

Various feeding and implant strategies are being utilized today. Timely research is needed to determine the best implant protocol to optimize production and carcass traits. The objective of this study was to compare the effects of combination implants administered at the start of the finishing phase and (or) at reimplant time on carcass grade traits among serially-slaughtered steers.

Materials and Methods

Animals. Yearling Charolais and Angus crossbred steers (n = 514) were obtained from a single source and blocked by initial weight (avg. 316.6 kg) into four groups. Implant treatments consisted of: CON = non-implanted control, ET = 28 mg estradiol benzoate plus 200 mg trenbolone acetate implanted on day 0, ETET = ET administered on day 0 and reimplanted on day 61, and SET = 20 mg estradiol benzoate plus 200 mg progesterone given on day 0 with a reimplant of ET on day 61. Steers were fed in 11 head pens and serially-slaughtered after 127, 148 and 169 days on a high concentrate diet.

Carcass data. Steers were slaughtered at a commercial facility and chilled at 0°C for approximately 66 hours postmortem. Carcass data for complete USDA quality and yield grade (USDA, 1989) determinations were collected by four University personnel. Masculinity characteristics were subjectively scored (bullock score: 5 = no evidence, 4 = slight; 3 = moderate; 2 = severe; 1 = extremely severe). This bullock score reflects bulbo-

cavernous muscle, crus of the penis and forequarter musculature (m. splenius) development.

Statistical analysis. The statistical model included weight block, implant treatment, days-fed and the implant treatment by days-fed interaction. Contrasts were used to assess linear or curvilinear responses across days-fed for carcass traits of interest within implant treatment groups. Least squares means for treatment effects reflect comparisons at a days-constant (148) endpoint. Appropriate days-based regression equations were used to predict carcass trait values at three additional endpoints (constant weight of 555.7 kg, constant s.c. fat thickness of 1.53 cm, and a constant marbling score of small[59]). These values were separated using Tukey's HSD procedure. Contrasts were conducted for effects of all implants compared to controls (CI); early versus late TBA administration (EL); and ET late implant versus SET (ST). Significance was reported at the .05 probability level.

Results and Discussion

The least squares means for slaughter and carcass traits stratified by implant treatment at a constant time-on-feed (148 days) are presented in Table II. The combination of estradiol and TBA produced heavier ($P < .05$) slaughter and carcass weights than controls. The weights of carcasses were significantly ($P < .05$) greater for the doubly implanted ET treatment than for the other three treatment groups. This increase in carcass weight was consistent with previous research of an estrogenic and TBA combination implant (Bartle et al., 1989; Foutz et al., 1989b; Mader, 1994; Perry et al., 1991; Huck et al., 1991) and

reimplanting of TBA (Trenkle, 1990; Wagner and Pritchard, 1992; Bartle et al., 1989; Bartle et al., 1988a). Increased ($P < .05$) carcass weights were noted in Gelbvieh cross steers implanted with estradiol and TBA on day 0 and reimplanted on day 77 (Bartle et al., 1992b).

Steers doubly implanted with ET (ETET) had higher ($P < .05$) dressing percentages than all other treatment groups. Galbraith et al. (1981) and Griffiths (1982) noted increased dressing percentages in steers implanted with TBA combinations. However, Bartle et al. (1992b) reported higher dressing percentages for a single Synovex implant on day 0 than for steers implanted with a Finaplix reimplant.

Slight increases ($P < .05$) in skeletal maturity were noted in carcasses from late ET implanted steers. Additionally, overall maturity was more ($P < .05$) advanced for SET implanted steers; however, there was no ($P > .05$) difference between the singularly and doubly implanted ET steers. However, no effects on carcass maturity were reported by Crouse et al. (1987), Huffman et al. (1991), and Trenkle (1985).

No dark cutters were detected in this study and there were no ($P > .05$) differences among treatment groups for lean maturity. It was observed by Apple et al. (1991), Foutz et al. (1989b), Crouse et al. (1987), Busby and Loy (1991), and Huffman et al. (1991) that there were no differences in lean color among steers implanted with anabolics. However, Brandt and Dikeman (1993) reported a high incidence ($P = .03$) of dark cutters for steers implanted with estradiol and TBA slaughtered 54 days post-implant, but not in steers on feed an additional 14 to 28 days.

TABLE II

LEAST SQUARES MEANS FOR CARCASS TRAITS STRATIFIED BY IMPLANT TREATMENT AT A CONSTANT TIME ON-FEED (148 DAYS)

Trait	Implant Treatment[a]				
	CON	ET	ETET	SET	Effect[b]
Number of Steers	126	128	128	128	
Slaughter weight, kg	538.4^{h}	573.0^{g}	584.4^{f}	580.8^{f}	CI EL
Hot carcass weight, kg	346.0^{i}	367.1^{h}	380.5^{f}	374.7^{g}	CI EL ST
Dressing percentage	64.3^{g}	64.1^{g}	65.1^{f}	64.5^{g}	EL ST
Skeletal maturity[c]	130.8^{h}	148.3^{g}	154.7^{f}	154.5^{f}	CI EL
Lean maturity[c]	146.5	145.9	148.0	150.2	
Overall maturity[c]	138.7^{h}	147.1^{g}	151.3^{g}	152.3^{f}	CI
Marbling score[d]	490.5^{f}	444.6^{g}	419.3^{h}	433.6^{gh}	CI EL
U.S. Prime, %	4.8	2.3	0.8	0	
U.S. Choice, %	81.8	76.0	58.1	72.3	
U.S. Select, %	13.5	21.7	39.5	27.7	
U.S. Standard, %	0	0	1.6	0	
Fat thickness, cm.	1.47	1.60	1.60	1.60	CI
Adjusted fat thickness, cm.	1.57^{g}	1.65^{g}	1.73^{f}	1.68^{g}	CI
Ribeye area, sq. cm.	78.3^{g}	84.2^{f}	86.3^{f}	85.5^{f}	CI
Ribeye area/cwt.	1.60	1.62	1.60	1.61	
Internal (KPH) fat, %	2.94	2.72	2.69	2.68	CI
Yield grade	3.65	3.57	3.64	3.60	
YG 1, %	2.4	3.9	3.8	5.4	
YG 2, %	17.6	27.6	27.0	18.6	
YG 3, %	50.4	39.4	41.3	47.3	
YG 4, %	23.2	20.5	18.3	19.4	
YG 5, %	6.4	8.7	9.5	9.3	
Bullock score[e]	4.6^{f}	4.3^{g}	4.0^{h}	4.2^{g}	CI EL ST

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

b Contrast effects: CI ($P < .05$) = control versus all implants; EL ($P<.05$) = early versus late TBA administration (ET vs. ETET); ST ($P < .05$) = 20 mg estradiol benzoate plus 200 mg progesterone on day 0 versus ET implants (ETET vs. SET).

[c] Carcass maturity scores: 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 for U.S. Choice.

[e] Bullock score: 5 = no evidence; 1 = severe bullock characteristics.

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

The overall maturity was slightly advanced ($P < .05$) for SET. Regardless of the significance of the higher maturity scores, all scores for carcasses regardless of treatment were well within "A"; these higher values are not likely to have any implications economically.

Steers that received no implants (control) had significantly ($P < .05$) higher bullock scores , reflecting less evidence of masculinity than steers administered TBA. Bullock scores were most pronounced in steers doubly implanted with TBA. The late administration of TBA by Foutz et al. (1989a and 1990) was similar to the above results. The slightly elevated bullock scores were of minor commercial implications since the means for all the treatments were between 4 (slight bullock tendencies) and 5 (no evidence).

Carcasses from TBA implanted (ET. ETET, SET) steers had significantly ($P < .05$) larger ribeye areas than carcasses from non-implanted (CON) steers. The increase in ribeye area agrees with the findings of Trenkle (1993), Rust and Schlegel (1989), Pritchard et al. (1990), and Nichols et al. (1992).

Internal (KPH) fat percentage was unchanged ($P > .05$) with implanting treatments. The mean weight for KPH percentage was found to be similar among treatments for implant trials by Nichols et al. (1992), Keane and Sherington (1985), Galbraith et al. (1983), and Kercher et al. (1990). Fat thickness (cm) was also unaffected ($P > .05$) by implant strategy. However, the adjusted fat thickness (cm) was significantly ($P < .05$) higher for the double implanted (ETET) treatment than for the other three treatments. Wagner and Pritchard (1992) also found that TBA implanted steers had more

($P < .01$) fat over the 12th rib than non-implanted steers. Notwithstanding, the yield grade did not differ ($P > .05$) among treatment groups. Hartman et al. (1989), Kercher et al. (1990), and Huffman et al. (1991) likewise observed no differences in USDA yield grades for TBA and estradiol combination implants. Pritchard et al. (1990) in a study between British and Continental crosses administered a combination estradiol and TBA based implant, on-test and reimplanted on day 77 reported that reimplanting tended to increase the ($P < .01$) rib fat thickness and thus, the final yield grade. Pritchard et al. (1990) concluded that the Gelbvieh cross steers would be exceedingly heavy if taken to a yield grade of 3.3 as were the Hereford x Angus crosses. In a similar trial, researchers, Huck et al. (1991) found no differences in yield grade among Angus and Angus-cross steers implanted with TBA and Synovex-S and Finaplix-S.

Marbling scores for carcasses from non-implanted (CON) steers were significantly ($P < .05$) higher than for ET, ETET and SET treatments. The lowest marbling score was noted in carcasses from the double ET implanted steers. Likewise, the double ET implant resulted in the lowest percentage (58.1%) of U.S. Choice carcasses as compared to carcasses from non-implanted (CON) steers (81.8%). All marbling score means were well within the Small degree. Upon reimplanting with TBA, a reduction in marbling scores was also reported by Bartle et al. (1989), Hicks et al. (1985) and Foutz et al. (1989a). Simms and Kuhl (1993) reported a non-significant ($P > .05$) reduction in marbling using a combination implant.

As the days-based slaughter endpoint increased, s. c. fat increased from .89 to 1.4 centimeters, in a study by Huffman et al. (1991). It was suggested that the degree of

marbling increased to the small degree within treatment of Synovex-S. In addition, the researchers reported the addition of a combination implant to Synovex-S , accounted for carcasses remaining at the slight degree (below 400 marbling score) at both .89 and 1.4 centimeters of backfat. Effects TBA may have on the marbling scores and thus quality grade may be related to the time that it was administered. Intramuscular fat being a late-maturing fat depot and TBA-estrogen increases muscle deposition, cattle would have to be fed longer to reach an equivalent quality grade as control cattle. Carcass weights were heavier ($P < .001$) in Gelbvieh cross steers that were also implanted with estradiol and TBA on day 0 and reimplanted on day 77. The researchers indicated that implanting TBA late in the finishing phase would reduce marbling scores, thus, the administration of TBA should be well before slaughter dates to allow intramuscular fat deposits to form.

Carcass traits adjusted to three additional constant endpoints are presented in Tables III through V. The use of multiple endpoints provides greater insight for producers to further examine the effects of implant treatments on steers slaughtered at a similar live weight, constant external fatness, or constant quality grade (similar marbling score). Weight-constant endpoints provide comparisons for developmental differences in carcass cutability and quality traits and reflect differences in degree of tissue maturation attributable to implants. The fat constant endpoint compared implant treatments at similar stages of tissue (fat thickness for cutability or marbling for quality) development. Each of these endpoints have practical marketing implications.

Constant Slaughter Weight. Implanted steers required about 30 fewer days of high-concentrate feeding to reach a constant slaughter weight endpoint than control steers

(Table III). At a constant slaughter weight, implanted steers had significantly larger ribeyes, less internal fat, similar fat thickness, and more desirable yield grades than carcasses from non-implanted steers. Increased ribeye areas were noted by Pritchard et al. (1990) in TBA implanted steers. However, the researchers reported an increased rib fat thickness and a higher yield grade from implanted steers than non-implanted steers. Unlike the constant days-fed comparison, few differences were noted among treatment groups for skeletal, lean and overall maturities when steers were compared at a similar weight. Additionally, implanted steers had significantly lower marbling scores, as in agreement with Anderson et al. (1991). Anderson et al. (1991) for a constant slaughter weight, noted TBA + E steers had lower marbling scores than the non-implanted steers. Pritchard et al. (1990) also agreed that feeding to a constant final weight would increase ribeye area, but reduce rib fat and yield grade with estradiol + TBA implants.

Constant Fat Thickness. Results of this study are similar to previous reports of anabolic implants having little effect on subcutaneous fat thickness (Pritchard et al., 1990), nonetheless, heavier ($P < .05$) slaughter and carcass weights as well as more advanced skeletal maturity were noted for carcasses from implanted steers. Higher ($P < .05$) amounts of internal fat, and smaller ribeyes were noted for carcasses from non-implanted steers than carcasses from implanted groups (Table IV). However, time-on-feed to a constant fat thickness was similar among treatment groups. As with other endpoint comparisons, yield grades were similar among treatment groups. Carcasses from non-implanted steers had higher ($P < .05$) marbling scores (small vs. slight) than carcasses

TABLE III

PREDICTED VALUES FOR CARCASS TRAITS STRATIFIED BY IMPLANT TREATMENT AT A CONSTANT SLAUGHTER WEIGHT (555 KG).

	Implant treatment[a]			
Trait	CON	ET	ETET	SET
Days-fed	160.9	133.3	129.8	131.2
Slaughter weight, kg	555.7	555.7	555.7	555.7
Hot carcass weight, kg	358.1	353.4	358.4	354.5
Dressing percentage	64.7[d]	63.5[e]	64.5[d]	63.8[e]
Carcass maturity[b]				
Skeletal	134.3	143.9	146.4	147.5
Lean	148.9[e]	141.5[e]	143.6[de]	144.1[de]
Overall	142.8	142.5	145.0	145.9
Marbling score[c]	508.4[d]	421.9[e]	393.7[e]	416.5[e]
Fat thickness, cm.	1.65	1.50	1.35	1.42
Adjusted fat thickness, cm.	1.75	1.57	1.42	1.45
Ribeye area, sq. cm.	78.1[e]	83.2[d]	85.0[d]	84.4[d]
Ribeye area/cwt..	1.54	1.66	1.67	1.68
Internal (KPH) fat, %	3.10[d]	2.68[d]	2.53[e]	2.48[e]
Yield grade	3.95[d]	3.43[e]	3.17[e]	3.21[e]

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

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

[c] Marbling score: 500 to 599 = "modest" (avg Choice), 400 to 499 = "small" (low Choice); 300 to 399 = "slight" (Select).

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

TABLE IV

PREDICTED VALUES FOR CARCASS TRAITS STRATIFIED BY IMPLANT TREATMENT AT A CONSTANT FAT THICKNESS (1.52 CM)

	Implant treatment[a]			
Trait	CON	ET	ETET	SET
Days-fed	137.8	131.9	134.3	134.4
Slaughter weight, kg.	529.0[e]	553.3[d]	534.1[d]	561.6[d]
Hot carcass weight, kg.	336.3[e]	351.2[d]	364.6[d]	360.4[d]
Dressing percentage	64.0[e]	63.4[e]	64.7[d]	64.0[e]
Carcass maturity[b]				
Skeletal	131.2[e]	143.1[d]	151.2[d]	151.5[d]
Lean	144.8	141.1	144.7	145.3
Overall	140.0	142.0	148.0	149.0
Marbling score[c]	466.0[d]	420.8[e]	392.4[e]	416.7[e]
Fat thickness, cm.	1.40	1.47	1.47	1.50
Adjusted fat thickness, cm.	1.50	1.55	1.57	1.55
Ribeye area, sq. cm.	78.3[e]	83.2[d]	85.3[d]	85.3[d]
Ribeye area/cwt.	1.65	1.67	1.65	1.66
Internal (KPH) fat, %	2.81[d]	2.68[e]	2.57[e]	2.52[e]
Yield grade	3.45	3.38	3.37	3.34

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

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

[c] Marbling score: 400 to 499 = "small" (low Choice); 300 to 399 = "slight" (Select).

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

from implanted groups (Table IV). The diminished marbling score was consistent with findings by Anderson et al. (1991b), Pritchard et al. (1990), and Preston et al. (1990).

Constant Marbling Score. It has been well documented that usage of estrogenic implants requires additional days on feed to reach a constant marbling score to that of non-implanted cattle (Preston et al., 1990; Anderson et al., 1991b). Preston et al. (1990) noted that it would require an additional 15.5 days to reach the same marbling score and Anderson et al. (1991b) reported 2, 8 and 15 additional days to reach mean marbling of Slight 50, Small 00 and Small 50, respectively. In this study, implanted steers required an additional 35 to 44 days-on-feed to reach the constant marbling score of Small^{59} (Table V). Unfortunately, the mean marbling score for several of the treatment groups was well above Small^{00} (the minimum marbling requirement for U.S. Choice and preferred score for this constant endpoint) on the first slaughter date. Thus, a score closer to the overall mean had to be selected to remain within the marbling range of each treatment group.

Once more, the implanted steers produced heavier ($P < .05$) slaughter and carcass weights along with a higher dressing percentage for doubly implanted steers. To reach the constant marbling score of Small ^{59}, the live weight and therefore, the carcass weights would be heavier in implanted cattle. Perry et al. (1991) reported a 25 to 45 kg additional live weight requirement by beef steers to reach a small degree of marbling. All implant treatments exhibited advanced ($P < .05$) skeletal, lean and overall maturities at a constant marbling score endpoint. Because implanted steers required additional days-on-feed, their carcasses were fatter ($P < .05$), both externally and internally, and produced less desirable yield grades than controls. Even though implanted steers exhibited larger ($P < .05$) ribeyes

TABLE V

PREDICTED VALUES FOR CARCASS TRAITS STRATIFIED BY IMPLANT TREATMENT AT A CONSTANT MARBLING SCORE (SMALL 59)

	Implant treatment[a]			
Trait	CON	ET	ETET	SET
Days-fed	125.2	160.1	168.9	169.0
Slaughter weight, kg.	509.7[e]	590.7[d]	615.4[d]	610.4[d]
Hot carcass weight, kg.	325.5[g]	382.3[f]	404.2[d]	397.6[e]
Dressing percentage	63.5[f]	64.5[e]	65.8[d]	65.4[d]
Carcass maturity[b]				
Skeletal	124.7[e]	153.2[d]	160.3[d]	159.8[d]
Lean	142.5[e]	149.5[d]	152.9[d]	157.8[d]
Overall	131.4[e]	151.0[d]	156.5[d]	158.0[d]
Marbling score[c]	459.0	459.0	459.0	459.0
Fat thickness, cm.	1.19[e]	1.78[d]	1.83[d]	1.83[d]
Adjusted fat thickness, cm.	1.27[e]	1.85[d]	2.03[d]	1.93[d]
Ribeye area, sq. cm.	78.5[e]	85.0[d]	87.6[d]	86.8[d]
Ribeye area/cwt.	1.69	1.55	1.53	1.54
Internal (KPH) fat, %	2.65[e]	2.75[d]	2.87[d]	2.93[d]
Yield grade	3.14[e]	3.87[d]	4.08[d]	4.03[d]

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

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

[c] Marbling score: 400 to 499 = "small" (low Choice);

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

than controls, the extra time-on-feed and weight necessary to attain small-plus marbling resulting in final yield grades approaching 4.0.

Extractable Lipids. In conducting the extractable lipids, the percentages were significantly lower ($P < .05$) for the ETET treatment with 4.6% than for the other three treatment groups (Table VI). ET and SET did not differ ($P > .05$) in lipid percentages. The non-implanted group had the highest ($P < .05$) lipid percentage of 5.8%. This group had the greatest percentage of USDA Choice carcasses (Table II) which indicated a higher intramuscular fat, that would account for a higher lipid percentage. Non-implanted steers were higher, though not significantly, than Zeranol implanted Limousin and Angus steers (Vanderwert et al., 1989). The researchers reported that there was a significant difference between the Angus and Limousin breeds, with Angus having the higher ($P < .05$) lipid percentage. In a breed-type effect on lipid composition of ribeye samples, the more highly marbled steaks from Angus cattle had 2 to 2.4 percent more ($P < .05$) total lipids than from Limousin, Simmental or Hereford steers. Ether extracts were not found to be different between implant groups and reimplanted (day 0, day 69) with Synovex-S + Finaplix and Synovex-S (Huck et al., 1991) or with Finaplix-S + Synovex-S (day 0 and 77), (Robbins et al., 1991). Calkins and Clanton (1984) noted that there were no differences between Ralgro and Compudose implants in ether extracts percentages.

The percentage of ether extractable fat has been closely related to the USDA marbling scores (Savell et al., 1986). The minimum fat necessary for varying marbling levels, had been chemically determined by Savell et al (1988). Utilizing the formula developed by Savell et al., (1986), the days to reach the 5.0% ether extractable lipid

necessary for the constant endpoint of a marbling score of small[59] are presented in Table VI. The days for the non-implanted control was lowest at 134.1 days and the double implanted ET would take the greatest number of days (157.1) to reach the constant marbling score of small[59].

Implications

Implanting results in heavier slaughter and carcass weights as well as larger ribeye areas at constant time, weight, and fatness endpoints. Results of this study revealed no adverse effects associated with implanting on lean color and the incidence of dark cutting beef. However, marbling score and thereby the percentage of U.S. Choice were depressed by implants. Steers of similar biological type (Continental European x British) administered a similar combination implant require approximately 35 to 44 more days of high concentrate feeding to deposit a similar amount of marbling to non-implanted controls, and after this time, yield grade is affected adversely.

TABLE VI

LEAST SQUARES MEANS FOR EXTRACTABLE LIPID % OF LONGISSIMUS MUSCLE FROM STEERS IMPLANTED WITH ESTRADIOL BENZOATE AND TRENBOLONE ACETATE AND FOR EXTRACTABLE LIPID TO REACH SMALL^{00} AND SMALL^{59} (CONSTANT MARBLING) FROM STEERS

	Implant treatment[a]			
Item	CON	ET	ETET	SET
Extractable lipid, %	5.8[c]	5.0[e]	4.6[d]	5.1[e]
Days to reach 5.0% lipid[b]	134.1	147.5	157.1	146.5
Days to reach 4.3% lipid[b]	121.2	130.2	141.9	135.4

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

[b] 5.0% lipid equal to Small ^{59} (constant marbling) and 4.3% lipid equal to Small ^{00} (Savell et al., 1986)

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

CHAPTER IV

EFFECTS OF COMBINATION IMPLANTS ON SHEAR FORCE AT THREE POSTMORTEM AGING TIMES FOR SERIALLY-SLAUGHTERED STEERS

Abstract

Steaks from five hundred carcasses were used to evaluate the effects of an androgenic implant, trenbolone acetate (TBA), in combination with estradiol benzoate. Implant treatments were: C = control or no implant, ET = 28 mg estradiol benzoate plus 200 mg TBA on day 0, ETET = ET administered on days 0 and 61, SET = 20 mg estradiol benzoate plus 200 mg progesterone given on day 0 and ET reimplanted on day 61. Shear force was assessed on ribeye steaks at a medium degree of doneness following three postmortem aging periods (7, 14 and 21 days). Implant treatment means were separated at four constant endpoints: time-on-feed (148 days), slaughter weight (555.7 kg), fat thickness (1.52 cm), and marbling score (small[59]). Steaks from steers reimplanted with ET had higher ($P < .05$) shear force (less tender) regardless of aging period. Steaks from steers reimplanted with ET were more ($P < .05$) variable than steaks from C steers through 14 days of postmortem aging. Aging steaks for 21 days removed most of the differences in shear force magnitude and variation. These results support postmortem

aging of steaks as recommended in the 1994 NCA National Beef Tenderness Plan. In two additional trials involving British cross steers singularly and reimplanted with estrogenic and TBA implants, no ($P > .05$) differences were noted in shear force values after 14 or 28 days of aging.

(Key Words: Beef, Shear force, Anabolic implants)

Introduction

Estrogenic implants are used by feedlots to increase rate and efficiency of gain. The addition of an anabolic compound, trenbolone acetate (TBA), to estrogenic compounds is additive for both performance and carcass traits. In a feedlot study using steers, Bartle et al. (1992b) reported that estradiol and TBA increase ribeye area without changing backfat levels. Their study also reported that marbling scores decreased when TBA was used.

Degree of marbling serves as a critical factor in the U.S. beef grading system to ensure tenderness and palatability. There is a concern for tenderness with lowered marbling scores from TBA usage. Foutz et al. (1989a) indicated there was only a slight decrease in tenderness (shear force) of ribeye steaks from steers implanted and reimplanted with TBA. Other researchers have reported no differences in tenderness among steaks from implanted cattle, but this research has been limited.

Most research on shear force has used steaks aged for 7 days. The time from slaughter until subprimal cuts arrive at retail outlets for consumer purchase has been estimated to be 17 days. The majority of cuts arrive between 10 and 30 days (Morgan et

al., 1991). The objective of this study was to examine the effects of an androgenic implant (TBA) in combination with estradiol benzoate administered to serially slaughtered feedlot steers on the shear force of ribeye steaks aged for 7, 14 and 21 days.

Materials and Methods

Animals. Crossbred steers (n = 500) from a similar background were blocked by weight and assigned to the following implant treatments: C = control, ET = 28 mg estradiol benzoate plus 200 mg TBA 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. The steers were serially slaughtered after 127, 148 and 169 days of high concentrate feeding. Following collection of carcass data at approximately 66 hours postmortem, a six inch boneless portion of the wholesale rib (10th through 12th rib) was fabricated from the left side of each carcass and vacuum packaged.

Two trials were conducted at other research stations to evaluate the effects of an androgenic implant, trenbolone acetate (TBA), in combination with estradiol benzoate and estradiol benzoate in combination with progesterone on the shear force of ribeye steaks over two aging periods (14 and 28 days). One hundred and ninety-two British cross steers were singularly implanted on day 0 in Trial 2. The implant treatments for Trial 2 were: C = control or no implant, SYN = 20 mg estradiol benzoate plus 200 mg progesterone A, REV = 24 mg estradiol benzoate plus 120 mg TBA, EB/TBA = 28 mg estradiol benzoate plus 200 mg TBA. Trial 3 included two hundred sixteen Angus cross steers administered

the following implant treatments: CON = control or no implant, S/S = 20 mg estradiol benzoate plus 200 mg progesterone administered on day 0 and reimplanted on day 63, ET = 28 mg estradiol benzoate plus 200 mg TBA on day 0, REV = 24 mg estradiol plus 120 mg TBA on day 0, SET = S/S on day 0 plus ET on day 63, and ET/ET = ET administered on day 0 and day 63.

Steak preparation and storage. After transport to the Oklahoma State University Meat Laboratory, the samples were crust frozen for 1 hour prior to fabrication. Three steaks (2.54 cm thick) were removed and vacuum packaged for aging periods of 7, 14 , and 21 days at 4°C. At the end of each aging period, appropriate steaks were boxed, blast frozen, and stored at -20°C. Trials 2 and 3 were handled as above, but aged for 14 and 28 days.

Cooking preparation. Steaks were thawed (4°C) for 24 hours and broiled at 177°C in an impingement oven to an internal temperature of 70°C. Temperatures were monitored with copper constantin constant thermocouple (Model #39658-J, Atkins Technical Inc., Gainesville, Fla.). Steaks were weighed prior to and after cooking to determine cook loss.

Warner-Bratzler Analysis. All steaks were cooled for two hours at room temperature (20°C) and cores (1.27 cm diameter) were removed parallel to the longitudinal direction of the muscle fibers. Six to eight cores were singularly sheared using a Warner-Bratzler shear attachment on an Instron Universal Testing Machine

shear through the sample core as the crosshead moved at 200 mm/min. The peak force (kg) was recorded by an IBM PS2 (Model 55 SX) using software provided by Instron Corporation and analyzed as an objective measurement for tenderness.

Proximate Analysis. A 1.3 cm steak was removed from the posterior end of each ribeye roll, completely denuded of exterior fat and epimysial connective tissue and stored in a Whirlpack® bag at -20°C. Proximate analysis of the samples was performed in duplicate according to procedures outlined by AOAC (1984). Samples were immersed in liquid nitrogen and powdered in a Waring® Commercial Blender (Model 34B122). A 3 g powdered sample was placed on 15 cm ashless filter paper, dried for 24 h at 100°C and desiccated for 1 h. Samples were then re-weighed to determine moisture content. After moisture determination, the samples were placed in a soxhlet for 24 h ether extraction. Samples were dried at 100°C for 12 h, desiccated and re-weighed to determine lipid content. The remaining portion of the sample was placed in a preweighed crucible and held for 8 h at 650°C to calculate ash. A 0.1 g powdered sample was completely combusted using a Nitrogen and Food Protein Determinator (LECO FP-428, St. Joseph, MI).

Statistical Analysis. The statistical model included animal 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 end points: days-fed (148), slaughter weight (555.7 kg), fat

thickness (1.52 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). These means were compared via least squares means analysis. Appropriate days-based regression equations were used to predict trait values at the other three endpoints. Tukey's HSD procedure was used to test values after adjusting error variances for regression estimates along the days-based lines and equality of variances was determined using the Levene's test for homogeneity of variance (Steel and Torrie, 1980). Contrasts were conducted for effects of all implants compared to controls (CI); early versus late TBA administration (EL); and ET late implant versus SET (ST). Significance was reported at the .05 probability level.

Results and Discussion

Least squares means and variances for shear force stratified by implant treatment and postmortem aging time are presented in Table VII. These values reflect comparisons at a constant time-on-feed (148 days). As expected, both magnitude and variability of shear force decreased with increased postmortem aging for all implant treatment groups. Steaks from steers reimplanted with ET were higher ($P < .05$) in shear force (less tender) than steaks from non-implanted steers regardless of aging period. However, no ($P > .05$) differences were noted between steaks from steers implanted singularly with ET at the onset of the finishing phase and steaks from non-implanted steers after 7 and 21 days of aging. Similar trends were detected for shear force variability among treatment groups. Steaks from steers reimplanted with ET were more ($P < .05$) variable than steaks from

TABLE VII

LEAST SQUARES MEANS AND VARIANCES FOR SHEAR FORCE (KG) AT A CONSTANT TIME-ON-FEED (148 DAYS) STRATIFIED BY IMPLANT TREATMENT AND POSTMORTEM AGING PERIOD.

	Implant treatment [a]			
Item	CON	ET	ETET	SET
Number of observations	121	125	127	127
Shear force mean, kg				
7-day aging	3.97[d]	4.18[d]	4.68[b]	4.41[c]
14-day aging	3.61[d]	3.86[c]	4.11[b]	4.03[bc]
21-day aging	3.58[d]	3.71[cd]	3.89[b]	3.81[bc]
Shear force variance, kg				
7-day aging	1.32[d]	1.60[cd]	2.35[b]	1.71[c]
14-day aging	1.02[d]	1.22[cd]	1.41[bc]	1.49[b]
21-day aging	1.11[b]	1.17[b]	1.05[c]	1.33[b]
Cooking loss, %				
7-day aging[e]	22.47	22.94	22.69	22.33
14-day aging[e]	22.49	22.35	22.45	22.33
21-day aging[e]	22.10	22.48	22.36	22.12

[a] CON=non-implanted 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 ET upon reimplanting at day 61

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

[e] All means in the same row were not significant (P > .05).

control steers through 14 days of postmortem aging. However, after 21 days of aging variability in shear force among treatment groups was minimal. ETET steaks were less ($P < .05$) variable than control steaks.

Predictions of tough, tender, and very tender steaks at 7, 14 and 21 days of aging for implant treatment groups are reported in Table VIII. Steaks from non-implanted steers produced fewer tough steaks through 14 days of aging and higher percentages of very tender steaks regardless of aging period. Steaks from implanted steers were more similar to control steaks in percentages of tough steaks after 21 days of aging.

The 7 day aging results are similar to those found by Foutz et al. (1989a) with 7 day aging. The workers noted that all implants had a higher ($P < .10$) WBS than for the nonimplant treatment after a 7 day aging period for the ribeye steaks, pointing out that TBA administered late tended to have adverse effects on shear force. Another study by Foutz et al. (1990) noted that after a 6 day aging time, TBA implanted steers produced steaks with slightly higher ($P < .05$) shear force values than non-implanted steers. However, no differences were noted among treatments for the percentage of tough (shear force values greater than 4.5 kg) steaks. Similarly, Huffman et al. (1991) reported a slight tendency ($P = .18$) of higher (less tender) shear force values in the 5 day aging of ribeye steaks from Finaplix and Finaplix + Synovex implanted Angus steers. In contrast, other researchers (Apple et al., 1991 and Crouse et al., 1987) with cooler aging for 6 to 7 days reported tenderness to be similar among TBA implants. Smith et al. (1989) noted improved ($P < .05$) tenderness after 7 days of aging, regardless of implant regiment. No

TABLE VIII

PREDICTIONS OF TOUGH, TENDER, AND VERY TENDER BASED ON SHEAR FORCE FOR IMPLANT TREATMENT GROUPS.

	Implant treatment[a]			
Item	CON	ET	ETET	SET
Tough steaks,%[b]				
7-day	21.5	30.4	55.1	42.5
14-day	8.3	16.8	26.0	22.0
21-day	14.9	13.6	18.9	19.7
Tender steaks, %[b]				
7-day	31.4	28.8	18.1	27.6
14-day	25.6	27.2	31.5	28.3
21-day	12.4	28.0	23.6	20.5
Very Tender steaks,%[b]				
7-day	47.1	40.8	26.8	29.9
14-day	66.1	56.0	42.5	49.6
21-day	72.7	58.4	57.5	59.8

[a] CON = non-implanted 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 ET upon reimplanting at day 61.

[b] Tough = shear force values of 4.5 kg or greater; Tender = shear force values from 3.9 to 4.5 kg; Very Tender = shear force less than 3.9 kg.

effects from implants with TBA were noted by either Johnson et al. (1984) or Trenkle (1990) in Charolais cross steers.

A significantly higher ($P < .05$) shear force was noted after a 14 day aging period, for the ribeye samples from an early feedlot castrated Angus bulls, implanted with Synovex-S and reimplanted 100 days later (Johnson et al., 1982). Increasing the aging time for samples to 10 days, Calkins et al. (1986) noted no differences ($P > .05$) between steers implanted with Zeranol and non-implanted steers from MARC II sires (one-fourth each of Angus, Gelbvieh, Hereford and Simmental). Across breed types, WBS was greatest for steaks from Simmental steers and intermediate for Simmental-Hereford and lowest for Angus steers implanted with Synovex and aged for 10 and 15 days postmortem (Shackelford et al., 1992b). Correspondingly, Angus bullock rib steaks required less ($P < .01$) shear force than samples from Gelbvieh crossbred rib steaks after 14 day aging, but there was a non-significant effect of implant treatment on the Warner-Bratzler shear values (Johnson et al., 1986).

In contrast to our findings, two implant studies conducted at different research stations noted no differences ($P > .05$) among treatments at 14 and 28-day aging period for the ribeye steaks. As presented in Table IX, the implants were administered to Red Angus, Black Angus and Hereford cross steers and in Table X, the steers were Angus crossbreeds. The implant regiments for Trial 2 were singularly implanted and in Trial 3, the implants included ET, (24 mg estradiol + 120 mg TBA), SET (administered on day 0 and ET on 63) and the last treatment of ET implanted on day 0 and reimplanted on day 63. Researchers have noted that as the percentage of Angus blood increases, the

TABLE IX

LEAST SQUARES MEANS AND VARIANCE FOR SHEAR FORCE (KG) STRATIFIED BY IMPLANT TREATMENT AND POSTMORTEM AGING PERIOD FOR TRIAL 2

	Implant Treatment[a]			
Item	CON	SYN	REV	EB/TBA
Number of observations	46	44	42	46
Shear force mean, kg				
14-day aging[b]	4.10	4.06	4.34	4.13
28-day aging[b]	4.00	3.92	4.01	3.98

[a] CON = no implant, SYN = 20 mg estradiol benzoate + 200 mg progesterone, REV = 24 mg estradiol (E2) + 120 mg trenbolone acetate (TBA), EB/TBA = 28 mg estradiol benzoate (20 mg E2) + 200 mg TBA.

[b] Means in the same row were not different (P > .05).

TABLE X

LEAST SQUARES MEANS AND VARIANCE FOR SHEAR FORCE (KG) STRATIFIED BY IMPLANT TREATMENT AND POSTMORTEM AGING PERIOD FOR TRIAL 3

	Implant Treatment[a]					
Item	CON	S/S	ET	REV	SET	ET/ET
Number of observations	11	11	11	11	10	11
Shear force mean, kg						
14-day aging[b]	4.03	3.97	3.95	3.85	3.97	4.05
28-day aging[b]	3.70	3.80	3.85	3.81	3.66	3.70

[a] CON = no implant; S/S = 20 mg estradiol benzoate (14 mg E2) + 200 mg progesterone implanted on d 0, reimplanted on d 63; ET = 28 mg estradiol benzoate (20 mg E2) + 200 mg trenbolone acetate (TBA); REV = 24 mg estradiol (E2) + 120 mg TBA; SET = S implanted d 0 and ET implanted on d 63; ETET = ET implanted on d 0, reimplanted on d 63.

[b] Means in the same row were not different (P > .05).

tenderness values are higher (Johnson et al., 1990; Williams et al., 1987 and Shackelford et al., 1992b). Later maturing cattle breeds (Gelbvieh, Simmental, Charolais) tended to have higher (less tender) shear values as purebreds and crosses (Shackelford et al., 1994b; Johnson et al., 1986; Vanderwert et al., 1989 and Jeremiah and Martin, 1977). This would imply that the breed types might have an effect on the WBS shear values, regardless of the aging period. However, an increased aging period, closest to the marketing of beef products, would have a significant effect upon the tenderness of the product.

Multiple Endpoints. Shear force values for implant treatment group comparisons at multiple endpoints (slaughter weight, fat thickness, and marbling score) are provided in Table XI. Shear force values were most similar among implant treatment groups for comparisons made at a constant slaughter weight. No ($P > .05$) differences were detected in shear force among treatment groups at 14 or 21 days of aging. At the fat constant endpoint comparison, steaks from ETET steers were higher ($P < .05$) in shear force than steaks from non-implanted steers through 21 days of postmortem aging.

Comparisons among implant treatment groups for shear force values at a constant level of marbling (quality) revealed significant differences through 14 days of postmortem aging. Steaks from steers reimplanted with ET had higher ($P < .05$) resistance to shear than control steaks. However, in steaks aged for 21 days, no ($P > .05$) differences were detected in shear force due to implant treatment.

TABLE XI

PREDICTED VALUES FOR SHEAR FORCE (KG) STRATIFIED BY IMPLANT TREATMENT AND POSTMORTEM AGING TIME FOR COMPARISONS AT A CONSTANT SLAUGHTER WEIGHT, FAT THICKNESS AND MARBLING SCORE

	Implant Treatment[a]			
Item	CON	ET	ETET	SET
Slaughter weight (555.7 kg.)				
Days-fed	160.9	133.3	129.8	131.2
7-day aging	4.01[c]	4.06[c]	4.63[b]	4.20[c]
14-day aging	3.64	3.65	4.01	3.78
21-day aging	3.64	3.52	3.75	3.58
Fat thickness (1.52 cm.)				
Days-fed	137.8	131.9	134.3	134.4
7-day aging	3.94[d]	4.05[cd]	4.67[b]	4.25[c]
14-day aging	3.40[c]	3.67[bc]	4.00[b]	3.77[b]
21-day aging	3.32[c]	3.53[bc]	3.75[b]	3.61[b]
Marbling score (Small[59])				
Days-fed	125.2	160.1	168.9	169.0
7-day	3.90[d]	4.29[c]	4.67[b]	4.67[b]
14-day	3.55[d]	3.89[cd]	4.27[bc]	4.41[b]
21-day	3.49	3.77	4.08	4.14

[a] CON=non-implanted 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 ET upon reimplanting at day 61.

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

Cooking losses. The least squares means for cooking losses as stratified by treatments are presented in Table I. The cooking losses were not ($P > .05$) different among the four treatments or the three aging periods for the ribeye steaks. These results are in agreement with the findings of Mitchell et al. (1991), Shackelford et al. (1991c), Morgan et al. (1993), and Foutz et al. (1990) for aging period and/or implant treatments. In contrast from this research, an increased fatness of Angus roasts accounted for greater cook losses than roasts from Holstein steers regardless of adjustment to the same carcass weight, marbling score or percentage ether extract of the lean (Armbruster et al., 1983). Armbruster et al. (1983) noted that for each 100 kg increase in carcass weight, cooking losses increased ($P < .0005$) 2.6 percentage units. In a study utilizing Synovex-S, Johnson et al. (1982) noted the implanted bulls had greater cooking losses ($P < .05$) than the non implanted bulls.

Proximate analysis. Significant differences were noted (Table XII) among implant treatments for all proximate analysis least squares means with the chemical composition of the steak samples. The protein percentage was significantly ($P < .05$) higher for the implanted steers than for the control (non-implanted) steers. Though, the percentage of protein was not ($P > .05$) significant between the late implanted steers, the single implanted ET was significantly ($P > .05$) lower than the double ET implanted cattle. This would indicate that the protein accretion was highest for TBA reimplanted cattle as noted by past researchers (Nichols et al., 1992) and for anabolic steroids (Desler and Jones, 1995). TBA implanted cattle did not differ in protein percentages in studies by

TABLE XII

LEAST SQUARES MEANS FOR PROXIMATE ANALYSIS VALUES OF RIBEYE FROM STEERS IMPLANTED WITH ESTRADIOL BENZOATE AND TRENBOLONE ACETATE

	Treatment[a]			
Item	CON	ET	ETET	SET
Number of samples	122	128	125	130
Ash, %	1.05[b]	1.06[bc]	1.08[a]	1.07[ac]
Moisture, %	72.30[b]	72.87[a]	73.07[a]	72.84[a]
Protein, %	21.34[c]	21.56[b]	21.81[a]	21.66[ab]
Extractable Lipid,%	5.78[a]	5.03[b]	4.56[c]	5.09[b]

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

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

researchers Hunt et al. (1991), Huck et al. (1991), Robbins et al. (1991), and Foutz et al. (1990).

The moisture percentage was significantly ($P < .05$) higher for all three implant treatments than for the control groups. The control group had the highest degree of marbling and in concurrence with past research, have the lowest moisture contents among the treatment groups (Thompson et al., 1988 and Savell et al., 1986). Robbins et al. (1991) and Foutz et al. (1989a and 1990) found no differences between TBA reimplanted treatments for moisture content.

The ash percentage was also different ($P < .05$) between the late ET administered groups (ETET and SET) and the non-treated group. There were no differences ($P > .05$) between the single ET implant and the control group. However, ETET and SET did not differ ($P > .05$), nor did SET and the ET treatments.

The lipid percentages were significantly ($P < .05$) higher for the control than the three implant groups (Table XII). This increased percentage would correspond with the lowest moisture percentage, since the two percentages are inversely related. The lowest ($P < .05$) percentage was noted in ET or SET treatments.

Implications

Steaks from steers receiving a single combination (estrogen + androgen) implant at the onset of the finishing phase are similar in shear force to steaks from non-implanted steers. Combination implants administered during the middle of the finishing phase tended to increase shear resistance and variability if steaks are aged for less than two weeks

postmortem. Aging steaks for a minimum of 21 days removed most of the differences in shear force magnitude and variation. These results support postmortem aging of steaks as recommended in the 1994 NCA National Beef Tenderness Plan (NCA, 1994). The extractable ether lipid percentage for ET and SET treatments would also support the minimum fat needed within the window of acceptable palatability as recommended by Savell et al. (1986 and 1988).

LITERATURE CITED

AOAC. 1984. Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists, Washington, D.C.

Adams, T.E., J.R. Dunbar, S.L. Beffy, W.N. Garrett, T.R. Fainula and Y.B. Lee. 1990. Feedlot performance of beef heifers implanted with Synovex-H: effect of melengestrol acetate, ovariectomy or active immunization against GNRH. J. Anim. Sci. 68:3079.

Anderson, P.T., L.J. Johnston and B.J. Johnson. 1992b. The effect of combined use of trenbolone acetate and estradiol implants on response of crossbred yearling steers to supplemental dietary protein. Minn. Beef Cattle Res. Rep. B-385:1 1.

Anderson, P.T. 1991a. Trenbolone acetate as a growth promotant. Compend. 3(7):1179.

Anderson, P.T., L.J. Johnson and R.V. Vatthauer. 1991b. Effects of combined use of trenbolone acetate and estradiol on crossbred steers slaughtered at three weight endpoints. J. Anim. Sci. 69 (Suppl. 1):84 (Abstr.).

Apple, J. K., M.E. Dikeman, D.D. Simms and D. Kuhl. 1991. Effects of synthetic hormone implants, singularly or in combinations, on performance, carcass traits, and l Longissmus muscle palatability of Holstein steers. J. Anim. Sci. 69:4437.

Armbruster, G., A.Y.M. Nour, M.L. Thonney and J.R. Stouffer. 1983. Changes in cooking losses and sensory attributes of Angus and Holstein beef with increasing carcass weight, marbling score or longissimus ether extract. J. Food Sci. 48:835.

Asghar, A. and A.R. Bhatti. 1987. Endogenous proteolytic enzyme in skeletal muscles: significance in muscle physiology and during postmortem storage. Adv. Food Research. 31:343.

Bartle, S.J., R.L. Preston, R.E. Brown and R.J. Grant. 1992a. Trenbolone acetate/estradiol combinations in feedlot steers: dose-response and implant carrier effects. J. Anim. Sci. 70:1326.

Bartle, S:J., R.L. Preston and R.C. Herschler. 1992b. Production responses to estradiol and trenbolone acetate combinations in feedlot heifers. Texas Tech Univ. Agric. Sci. Tech. Rep. No. T-5-317:135.

Bartle, S.J., R.L. Preston and J.A Rogers. 1991. Evaluation of an estradiol/testosterone implant for feedlot heifers. Texas Tech Univ. Agric. Sci. Tech. Rep. No. T-5-297:54.

Bartle, S.J., R.L. Preston, R.E. Brown and R.J. Grant. 1990. Trenbolone acetate/estradiol and estradiol/progesterone reimplant study in feedlot steers. J. Anim. Sci. 68 (Suppl. 1):87 (Abstr.).

Bartle, S.J., R.L. Preston, R.E. Brown and R.J. Grant. 1989. Revalor (trenbolone acetate and estradiol) and Synovex reimplant study in steers. Texas Tech Univ. Agric. Sci. Tech. Rep. No. T-5-263:32.

Bartle, S.J., R.L. Preston and D.J. Smith. 1988a. Dual implants of feedlot steers with trenbolone acetate (Finaplix) and STEER-oid or Synovex-S estradiol implants. Texas Tech Univ. Agric. Sci. Tech. Rep. No. T-5-251:53.

Bartle, S.J., R.L. Preston, R.E. Brown and R.J. Grant. 1988b. Dose-response relationship of trenbolone acetate/estradiol combinations in feedlot heifers. Texas Tech Univ. Agic. Sci. Tech. Rep. No. T-5-251:58.

Bartos, L., C. Franc, D. Rehak and Stipkova. 1993. A practical method to prevent dark-cutting (DFD) in beef. Meat Sci. 34:275.

Belk, K., H.R. Cross and D. Nash. 1989. Effects of trenbolone acetate, estrogens on steers explored. *Feedstuffs* 61(50):15.

Borger, M.L., L.L. Wilson, J.D. Sink, J.H. Ziegler and S.L. Davis. 1973a. Zeranol and dietary protein level effects on live performance, carcass merit certain endocrine factors and blood metabolite levels of steers. J. Anim. Sci. 36:706.

Borger, M.L., J.D. Sink, L.L. Wilson, J.H. Ziegler and S.L. Davis. 1973b. Zeranol and dietary protein level effects on DNA, RNA and protein composition of three muscles and the relationship to serum insulin and GH levels of steers. J. Anim. Sci. 36:712.

Botts, R.L. 1992. Evaluation of various programs of Synovex-S, Finaplix-S and estradiol 17ß/trenbolone acetate in feedlot steers of three distinct breed types. J. Anim. Sci. 70(Suppl. 1):280 (Abstr.).

Bouffault, J.C. and J. P. Willemart. 1983. Anabolic activity of trenbolone acetate alone or in association with estrogens. In: Anabolics in Animal Production. (Ed.) E.

Meissonnier and J. Mitchell-Vigneron, pp 155-179. Offfice International des Epizooties, Paris.

Brandt, R.T. and M.E. Dikeman. 1993. Effect of reimplant scheme and additional time on feed on performance and carcass traits of finishing steers. J. Anim. Sci. 71 (Suppl. 1): 87 (Abstr.).

Brethour, J.R. 1985. Implant combinations involving trenbolone for steers and bulls. J. Anim. Sci. 61(Suppl. 1):463 (Abstr.).

Busby, D. and D. Loy. 1991. Feedlot performance and carcass characteristics of steer calves implanted with combination implants. Iowa St. Beef/Sheep Rep. A.S. Leaflet R818:89. Ames, IA.

Buttery, P.J. and P.A. Sinnett-Smith. 1984. The mode of action of anabolic agents. In: Roche, J. F. and D. O'Callaghan (Ed.). In: Manipulation of Growth in Farm Animals. p. 21 1. Martinus Nijhoff Publishers, Hingham, MA.

Buttery, P.J., B.G. Vernon and J.T. Pearson. 1978. Anabolic agents-some thoughts on their mode of action. Proc. Nutr. Soc. 37:31 1.

Calkins, C.R. and S.C. Seideman. 1988. Relationships among calcium-dependent protease, cathepsins B and H, meat tenderness and the response of muscle to aging. J. Anim. Sci. 66:1186.

Calkins, C.R., Koohmaraie, M. and S.C. Seideman. 1987. The relative impact of Ca-dependent protease and cathepsins on beef tenderness and the response of muscle to cooler aging. J. Anim. Sci. 65 (Suppl. 1): 290 (Abstr.).

Calkins, C.R., D.C. Clanton, T.J. Berg and J.E. Kinder. 1986. Growth, carcass and palatability traits of intact males and steers implanted with zeranol or estradiol early and throughout life. J. Anim. Sci. 62:625.

Calkins, C.R. and D.C. Clanton. 1984. Carcass and palatability characteristics of intact males and steers implanted with Ralgro® or Compudose®. J. Anim. Sci. 59 (Suppl. 1): 225 (Abstr.).

Chaudhary, Z.I., M.A. Price and M. Makarechian. 1985. Effects of zeranol on weight gain, bone growth and other carcass traits in steers and bulls. Can. J. Anim. Sci. 65:835.

Cohen, R.D.H., B.D. King, E.D. Janzen and H.H. Nicholson. 1991. The effect of castration age, method and implant regime on growth and carcass traits of male beef cattle. Can. J. Anim. Sci. 71:301.

Cohen, R.D.H. and J.A. Cooper. 1983. Avoparcin, monensin and zeranol for steers finishing on barley diets. Can. J. Anim. Sci. 63:361.

Combs, J.J. and D.D. Hinman. 1984. A comparison of Compudose, Ralgro and Synovex-S implants for feedlot steers. J. Anim. Sci. 59(Suppl. 1):479 (Abstr.).

Corah, L.R., L.Fink, G.H. Kiracofe and M.McKee. 1979. Sexual development and carcass traits of bulls after sequential implanting with zeranol. J. Anim. Sci. 49(Suppl. 1):287 (Abstr.).

Cranwell, C.D., J.A. Unruh, D.D. Simms and J.R. Brethour. 1992. Performance and carcass characteristics of cull beef cows implanted with growth promotants and fed a high concentrate ration. Kansas St. Cattlemen's Day 651:85. Kansas State Univ. Manhattan, KS.

Cross, H.R. and K.E. Belk. 1989. Two-edged sword: anabolic implants improve yield, hinder quality. *Beef*. Vol. 26, no 1 A: I 1.

Crouse, J.D., M. Koohmaraie and S.D. Seideman. 1991. The relationship of muscle fibre size to tenderness of beef. Meat Sci. 30:295.

Crouse, J.D., L.V. Cundiff, R.M. Koch, M. Koohmaraie and S.C. Seideman. 1989. Comparisons of *Bos indicus* and *Bos taurus* inheritance for carcass beef characteristics and meat palatability. J. Anim. Sci. 67:2661.

Crouse, J.D., B.D. Schanbacher, H.R. Cross, S.C. Seideman and S.B. Smith. 1987. Growth and carcass traits of heifers as affected by hormonal treatment. J. Anim. Sci. 64:1434.

Culp, G.R., Z.I. Carpenter, G.C. Smith and G.W. Davis. 1973. Postrigor aging effects on beef tenderness. J. Anim. Sci. 37 (Pt. 1):258 (Abstr.)

Davey and Gilbert. 1969. Studies in meat tenderness. 7. changes in the fine structure of meat during aging. J. Food Sci. 34:69.

Davis, K.A., D. L. Huffman and J.C. Cordoray 1975. Effect of mechanical tenderization, aging and pressing on beef quality. J. Food Sci. 40:1222.

Dayton, W.R. and J.V. Schollmeyer. 1981. Immunocytochemical localization of a calcium-activated protease in skeletal muscle cells. Exp. Cell Res. 136:423.

Deans, R.J. W.J. Van Arsdell, E.P. Reineke and L.J. Bratzler. 1956. The effect of progesterone-estradiol implants and stilbestrol feeding on feed lot performance and carcass characteristics of steers. J. Anim. Sci. 15:1020.

Desler, M. and S. Jones. 1995. Anabolic steroid and glucocorticoid action on muscle growth. Beef Cattle Rep. MP-62A:41. Agric. Res. Div. Univ. of Neb. Lincoln, NE.

Dutson, T.R. and A.M. Pearson. 1985. Postmortem conditioning of meat. In: Pearson, A.M. and T.R. Dutson (Ed.), Advances in Meat Research, Vol. 1, p. 45.

Eck, T.P. and L.R. Corah. 1993a. Implant comparisons in feedlot steers and heifers. J. Anim. Sci. 70 (Suppl. 1):53 (Abstr).

Eck, T.P. and L.R. Corah. 1993b. Implant comparisons in feedlot steers and heifers. Kansas State University's Cattlemen's Day. 678:131. Kan. St. Univ. Manhattan, KS.

Eilers. J.D., J.D. Tatum, J.B. Morgan and G.C. Smith. 1994. The effects of electrical stimulation and postmortem aging on beef tenderness. Colorado State Univ. Beef Prog. Rep.:11. Colo. State Univ. Ft. Collins, CO.

Epley, R.J. 1978. Dark-cutting beef. Minnesota. University Agricultural Ext. Serv. 392:4. Univ. of Minnesota. St. Paul, MN.

Faulkner, D.B., F.K. McKeith, L.L. Berger, D.J. Kesler and D.F. Parrett. 1989. Effect of testosterone propionate on performance and carcass characteristics of heifers and cows. J. Anim. Sci. 67:1907.

Field, R.A., M.L. Riley, and Yet-Oy Chang. 1971. Free amino acid changes in different aged bovine muscles and their relationship to shear values. J. Food Sci. 36:611.

Fisher, A.V., J.D. Wood and O.P Whelehan. 1986. The effects of a combined androgenic-oestrogenic anabolic agent in steers and bulls. Anim. Prod. 42:203.

Forrest, R.J. 1975. Effects of castration, sire and hormone treatments on the quality of rib roasts from Holstein-Friesian males. Can. J. Anim. Sci. 55:287.

Forrest, R.J. and L.A. Sather. 1965. The effect of hormones on the rate of gain and feed consumption of Holstein-Friesian steers slaughtered at 340, 522 and 703 kilograms body weight. Can. J. Anim. Sci. 45:173.

Foutz, C.P., D.R. Gill, H.G. Dolezal, R.T. Botts, T.L. Gardner and F.N. Owens. 1990. Synovex-S, Finaplix-S, or Revalor implants for feedlot steers. Anim. Sci. Rep. MP-129:100. Okla. State Univ. Stillwater.

Foutz, C.P., H.G. Dolezal, D.R. Gill, C.A. Strasia, T.L. Gardner, E.D. Tinker and F.K. Ray. 1989a. Effects of trenbolone acetate in yearling feedlot steers on carcass grade traits and shear force. Anim. Sci. Rep. MP-127: 272. Okla. State Univ. Stillwater.

Foutz, C.P., H. G. Dolezal, D.R. Gill, C.A. Strasia, T.L. Gardner and F.K. Ray. 1989b. Trenbolone acetate effects on carcass traits of yearling feedlot steers. J. Anim. Sci. 67 (Suppl. 1):434 (Abstr.)

Foutz, C.P., D.R. Gill, H.G. Dolezal, T.L. Gardner and R.T. Botts. 1989c. Synovex-S and trenbolone acetate implants for feedlot steers. J. Anim. Sci. 67 (Suppl. 1):474 (Abstr.)

Fox, D.G., T.C. Perry and D.H. Beermann. 1989. Effect of Revalor implants on performance, carcass quality and boxed beef yield in steers of three breed types. J. Anim. Sci. 68 (Suppl. 1):527 (Abstr.).

Galbraith, H. 1980. The effect of trenbolone on acetate growth, blood hormones and metabolites and nitrogen balance of beef heifers. Anim. Prod. 30:389.

Galbraith, H., J.R. Scaife and G.F.M. Paterson. 1983. Effect of trenbolone acetate combined with oestradiol-17b on the response of steers to changes in dietary protein. J. Agric. Sci. (Camb) 101:249.

Galbraith, H., M. Kay and L. Scott. 1981. Response of finishing steers to monensin sodium supplementation and implantation with trenbolone acetate combined with oestradiol-17ß. Anim. Prod. 32:378 (Abstr.).

Galbraith, H. and J. H. Topps. 1981. Effect of hormones on the growth and body composition of animals. Nutrition Abst. and Reviews. Series B. 51(8): 521.

Gill, D.R., F.N. Owens, R.A. Smith and R.B. Hicks. 1987. Effects of trenbolone acetate with or without estradiol, Synovex-H and Ralgro on the rate and efficiency of gain by feedlot steers. Okla. Ag. Expt. Sta. Res. Rep. UPI 19:340.

Gill, D.R., J.J. Martin, F.N. Owens and D.E. Williams. 1983. Implants for feedlot bulls. Okla. Ag. Expt. Sta. Res. Rep. MPI 14:60.

Goll, D.E., Y. Otsuka, P.A. Againis, J.D. Shannon, K.S. Sheridhar and M. Mugurama. 1983. Role of muscle proteinases in maintenance of muscle integrity and mass. J. Food Biochem. 7:137.

Goll, D.E., M.H. Stromer, D.G. Olson, W.R. Dayton, A. Suzuki and R M. Robson. 1974. The role of myofibrillar proteins in meat tenderness. Proc Meat Ind. Res. Conf. 24: Chicago, Ill.

Goodman, J.P., A.L. Slyter and L.B. Embry. 1982. Effect of intravaginal devices and Synovex-H implants on feedlot performance, cyclic activity and reproductive tract characteristics of beef heifers. J. Anim. Sci. 54:491.

Gordon, S.J., H.L. Miller, D.H. Gee, B.A. Petitjean and R.L. Hanson. 1986. Effects of anabolic implants on reproductive function, carcass characteristics and performance in postweaned beef bulls. South Dakota Beef Rep., CATTLE 86-22:101.

Grandadam, J.A., J.P. Schied, A. Jobard, H. Dreux and J.M. Boisson. 1975. Results obtained with trenbolone acetate in conduction with estradiol 17ß in veal calves, feedlot bulls, lambs and pigs. J. Anim. Sci. 41:969.

Grandin, T. 1992. Problems with bruises and dark cutters in slaughter steers/heifers. National Beef Quality Audit, Final Report, p.147. National Cattlemen's Assct. Denver, CO.

Gransworthy, P.C., D.J.A. Cole, M. Grantley-Smith, D.W. Jones, and A.R. Peters. 1986. The effect of feedng period and trenbolone acetate on the potential of culled dairy cows for beef production. Anim. Prod. 43:385.

Greathouse, J.R., M.C. Hunt, M.E. Dikeman, L.R. Corah, C.L. Kastner and D.H. Kropf. 1983. Ralgro-implanted bulls: performance, carcass characteristics, longissimus palatability and carcass electrical stimulation. J. Anim. Sci. 57:355.

Gregory, K.E., S.C. Seideman and J.J. Ford. 1983. Effects of late castration, zeranol and breed group on composition and palatability characteristics of longissimus muscle of bovine males. J. Anim. Sci. 56:781.

Griffiths, T.W. 1982. Effects of trenbolone acetate and resorcylic acid lactone on protein metabolism and growth in steers. Anim. Prod. 34:309.

Hartman, P.G., G. Kuhl, D. Simms, R. Ritter and P. Houghton. 1989. Effects of Finaplix in combination with Ralgro-and Synovex on performance and carcass characteristics of steers and heifers. Kansas State Cattlemen's Day 567: 100. K. State Univ., Manhattan.

Hawkins, D.R., A.S. Babiker, R.A. Merkel and P.R. Sweeney. 1986. The effect of Ralgro implants on feedlot performance and carcass characteristics of young beef bulls. Mich. St. Univ., Rep. of Beef Cattle-Forage Res. 473:1 10.

Hawkins, E.W., L.E. Orme, R. Dyer, L. Ogden, R.L. Park and R.A. Field. 1987. Comparisons between zeranol implanted and non-implanted bulls and steers. Proc. Annu. Meet. West. Sect. Am. Soc. Anim. Sci. 38:147.

Heitzman, R.J., D.N. Gibbons, W. Little and L.P. Harrison. 1981. A note on the comparative performance of beef steers implanted with the anabolic steroids trenbolone acetate and oestradiol-17ß alone or in combination. Anim. Prod. 32:219.

Heitzman, R.J. 1979. The efficacy and mechanism of action of anabolic agents as growth promoters in farm animals. J. Steroid Biochem. 11:927.

Heitzman, R.J. and D.J. Harwood. 1977. Residue levels of trenbolone and oestradiol-17ß in plasma and tissues of steers implanted with anabolic steroid preparations. Br. Vet. J. 133:564.

Hermel, S.R. 1994. Implants don't lower quality, tenderness. *Beef* 30(7):30.

Hickman, P.S., R.T. Brandt, Jr., D.M. Henricks, J.S. Stevenson and J.E. Minton. 1994. Payout characteristics of anabolic agents from Synovex®, Finaplix®, and Revalor® implants in finishing yearling steers. Kansas State University Cattlemen's Day. 704:16. K. State Univ., Manhattan.

Hicks, R.B., D.R. Gill, L.H. Carroll, J.J. Martin and C.A. Strasia. 1985. The effect of Compudose and Finaplix alone and in combination on growth of feedlot steers. Okla. Ag. Expt. Sta. Res. Rep. ND 117:269.

Hodges, J.H., V.R. Cahill and H.W. Ockerman. 1974. Effect of vacuum packaging on weight loss, microbial growth and palatability on fresh beef wholesale cuts. J. Food Sci. 39:143.

Hoechst-Roussel. 1995 Managing dark cutters. Dialogue 3(1). Hoechst-Roussel Agri-Vet Co. Kansas City, MO.

Hopkins, T.D. and M.E. Dikeman. 1987. Effects of oestradiol-17b implantation on performance, carcass traits, meat sensory traits and endocrine aspects of bulls and steers. Meat Sci. 21:51.

Huck, G.L., R.T. Brandt, M.E. Dikeman, D.D. Simms and G.L. Kuhl. 1991. Frequency and timing of trenbolone acetate implantation on steer performance, carcass characteristics and beef quality. J. Anim. Sci. 69(Suppl. 1):560 (Abstr.).

Huffman, R.D., R.L. West, D.L. Pritchard, R.S. Sand and D.D. Johnson. 1991. Effect of Finaplix and Synovex implantation on feedlot performance and carcass traits, Florida Beef Cattle Res. Rep.:97.

Hunt, D.W., D.M. Henricks, G.C. Skelley and L.W. Grimes. 1991. Use of trenbolone acetate and estradiol in intact and castrate male cattle: effects on growth, serum hormones and carcass characteristics. J. Anim. Sci. 69:2452.

Hutcheson, D.P., J.P. Rains and J.W. Paul. 1993. The effects of different implant and feed additive strategies on performance and carcass characteristics in finishing heifers: A review. Prof. Anim. Sci. 9:132.

Isaacson, W., S. Jones and R. Krueger. 1991. Androgenic steroids suppress glucocorticoid synthesis. Nebraska Beef Cattle Rep. UP-56:61. Univ. of Neb., Lincoln.

Isaccson, W., S. Jones and R. Krueger. 1992. Trenbolone acetate and zeranol effects on cortisol release from the adrenal gland. Nebraska Beef Cattle Rep. MP-58:48. Univ. of Neb. Lincoln, NE.

Jennings, T.G., B.W. Berry, and A.L. Joseph. 1978. Influence of fat thickness, marbling, and length of aging on beef palatability and shelf life characteristics. J. Anim. Sci. 46: 658.

Jeremiah, L.E. and A.H. Martin. 1978. Histological and shear properties of bovine muscle and their alteration during postmortem ageing. Meat Sci. 2:169.

Jeremiah, L.E. and A.H. Martin. 1977. The influence of sex, within breed-of-sire groups, upon the histological properties of bovine longissimus dorsi muscle during postmortem aging. Can. J. Anim. Sci. 57:7.

Johnson, M.H., C.R. Calkins, R.D. Huffman, D.D. Johnson, and D.D. Hargrove. 1990. Differences in cathepsin B + L and calcium-dependent protease activities among breed type and their relationship to beef tenderness. J. Anim. Sci. 68:2371.

Johnson, B.J., M. R. Hathaway, P.T. Anderson, J.C. Meiske, R.S. Frey and W.R. Dayton. 1993. Effect of combined trenbolone acetate and estradiol implants on growth, carcass characteristics and biochemical parameters of steers. J. Anim. Sci. 71 (Suppl. 1):139 (Abstr.).

Johnson, D.D., J.W. Savell, G.C. Smith, D.R. Gill, D.E. Williams, L.E. Walters and J.J. Martin. 1984. Relationship of growth stimulants. and breed groups on carcass characteristics and palatability of young bulls. J. Anim. Sci. 58:920.

Johnson, L.J., D.L. Cross, G.C. Skelley and T.C. Jenkins. 1987. Effect of Compudose controlled release implants on growing and finishing beef heifers. J. Anim. Sci. 65(Suppl. 1):74 (Abstr.).

Johnson, R.C., D.H. Gee, W.J. Costello and C.W. Carlson. 1986. Effects of anabolic implants and breed group on carcass traits and palatability characteristics of bullock beef. J. Anim. Sci. 62:399.

Johnson, R.C., D.H. Gee, B.C. Paterson and L.B. Bruce. 1982. Effects of Synovex-S implants on carcass characteristics of intact and early feedlot period castrated Angus bulls. J. Anim. Sci. 57(Suppl. 1):224(Abstr).

Jones, S.D.M., L.E. Jeremiah, A.K.W. Tong, S. Lutz and W.M. Robertson. 1991. The effects of marbling level, electrical stimulation, and postmortem aging on the cooking and palatability properties of beef rib-eye steaks. Can. J. Anim. Sci. 71:1037.

Jones, S.D.M., J.A. Newman, A.K.W. Tong, A.H. Martin and W.M. Robertson. 1986. The effects of two shipping treatments on the carcass characteristics of bulls implanted with zeranol and unimplanted steers. J. Anim. Sci. 62:1602.

Jones, S.J., R.D. Johnson, C.R. Calkins and M.E. Dikeman. 1991. Effects of trenbolone acetate on carcass characteristics and serum testosterone and cortisol concentrations in bulls and steers on different in management and implant schemes. J. Anim. Sci. 69:1363.

Jouquey, A., M. Mouren, J. Salmon. 1983. Analytical methods for trenbolone. In: Anabolics in Animal Production. (Ed. E. Meissonnier and J. Mitchell-Vigneron), pp 432-425. Offfice International des Epizooties, Paris.

Keane, M.G. and M.J. Drennan. 1987. Lifetime growth and carcass composition of heifers and steers non-implanted or sequentially implanted with anabolic agents. Anim. Prod. 45:359.

Keane, M.G. and J. Sherington. 1985. Effects of frequency of implantation and type of anabolic agent on performance and carcass traits of finishing steers. Br. J. Agric. Res. 24:161.

Kennett, A.M. and B.D. Siebert. 1987. Effects of implants of oestradiol plus progesterone on the growth rate and intramuscular fat composition of steers raised in southern Australia. Aust. J. Exp. Agric. 27:747.

Kercher, C.J., D.C. Rule and R.R. Jones. 1990. Hormone implant combinations for growing-finishing beef steers. Proc. Annu. Meet. West. Sect. Am. Soc. Anim. Sci. 41:442.

Koohmaraie, M. 1994. Muscle proteinases and meat aging. Meat Sci. 36:93.

Koohmaraie, M. G. Whipple, D.H. Kretchmar, J.D. Crouse and H.J. Mersmann. 1991. Postmortem proteolysis in longissimus muscle from beef, lamb and pork carcasses. J. Anim. Sci. 69:617

Koohmaraie, M. 1990. Quantification of Ca^{2+} dependent protease activities by hydrophobic and ion-exchange chromatography. J. Anim. Sci. 68:659.

Koohmaraie, M., S.C. Seideman, J.E. Schollmeyer, T.R. Dutson, and AS. Babiker. 1988a. Factors associated with the tenderness of three bovine muscles. J. Food Sci. 53:407.

Koohmaraie, M., A.S. Babiker, R.A. Merkel and T. R. Dutson. 1988b. Role of Ca^{++}-dependent proteases and lysosomal enzymes in postmortem changes in bovine skeletal muscle. J. Food Sci. 53:1253.

Koohmaraie, M., S.C. Seideman, J.E. Schollmeyer, T.R. Dutson and J.D. Crouse. 1987. Effect of post-mortem storage on Ca^{++}-dependent proteases, their inhibitor and myofibril fragmentation. Meat Sci. 19:187.

Kuhl. G.L., D.D. Simms, D.A. Blast, and C. L. Kastner. 1993a. Comparison of Synovex-S and two levels of Revalor-S in heavy-weight holstein steers. Kansas State University Cattlemen's Day 678:134. Kan. St. Univ., Manhattan.

Kuhl, G.L., D.D. Simms and D.A. Blasi. 1993b. A comparison of implanting heavy weight Holstein steers with either estradiol plus progesterone or two levels of estradiol plus trenbolone acetate. J. Anim. Sci. 71 (Suppl. 1):86 (Abstr.).

Kuhl, G.L., D.D. Simms, and P.D. Hartman. 1989. Sequential implanting with Synovex-S or Synovex-S + Finaplix-S on steer performance and carcass characteristics. J. Anim.Sci. 67 (Suppl. 1):434 (Abstr.).

Lee, C.Y., D.M. Henricks, G.C. Skelley and L.W. Grimes. 1990. Growth and hormonal response to intact and castrate male cattle to trenbolone acetate and estradiol. J. Anim. Sci. 68:2682.

Lemieux, P.G., F. M. Byers and G. T. Schelling. 1988. Anabolic effects on rate, composition and energetic efficiency of growth in cattle fed forage and grain diets. J. Anim. Sci. 66:1824.

Locker, R. H. 1960. Degree of muscular contraction as a factor in tenderness of beef. Rood Res. 25:304.

Locker, R.H., G.J. Daines, W.A. Carse and N.G. Leet. 1977. Meat tenderness and the gap filaments. Meat Sci. 1:87.

Lomas, :L.W. 1983. Effect of Bovatec and Synovex-S implants on finishing steer performance. Kansas State University's Cattlemen's Day, Rep. of Prog. 427:112. Kansas Agric. Exp. Sta., Manhattan.

Lorenzen, C.L., D.S. Hale, D.B. Griffin, J.W. Savell, K.E. Belk, T.L. Frederick, M.F. Miller, T.H. Montgomery and G.C. Smith. 1993. National beef quality audit: survey of producer-related defects and carcass quality and quantity attributes. J. Anim. Sci. 71:1495.

Machlin, L.J. 1972. Effect of porcine growth hormone on growth and carcass composition of the pig. J. Anim. Sci. 35:794.

Marsh, B.B. 1983. Effect of early-postmortem muscle pH and temperature on meat tenderness. Proc. Recip. Meat Conf. 36:131.

Martin, A.H., H.T. Fredeen, and G.M. Weiss. 1971. Tenderness of beef longissimus muscle from steers, heifers, and bulls as influenced by source, post-mortem aging, and carcass characteristics. J. Food Sci. 36:619.

Mader, T.L. 1994. Effect of implant sequence and dose on feedlot cattle performance. J. Anim. Sci. 72:277.

Martin, A.H., H.T. Fredeen and G.M. Weiss. 1971. Tenderness of beef longissimus dorsi muscle from steers, heifers and bulls as influenced by source, post-mortem aging and carcass characteristics. J. Food Sci. 36:619.

Mayer, M. and R. Rosen. 1975. Interaction of anabolic steroids with glucocorticoid receptor sites in rat muscle cytosol. Am. J. Physiol. 229:1381.

McNamara, J.P. 1986. Mode of action of estrogenic implants in beef bulls and steers in altering carcass fat. Washington State Univ. Proc. Beef Res. Info. Day. p. 12.

Meyer, H.D. and M. Rapp. 1985. Estrogen receptor in bovine skeletal muscle. J. Anim. Sci. 60:294.

Michel, G. and E.E. Baulieu. 1983. The mode of action of anabolics. In: Anabolics in Animal Production. (Ed. E. Meissonnier and J. Mitchell-Vigneron), pp 53-64. Offfice International des Epizooties, Paris.

Minks, D. and W. C. Stringer. 1972. The influence of aging beef in vacuum. J. Food Sci. 37:736.

Mitchell, G.E., J.E. Giles, S.A. Rogers, L.T. Tan, R. J. Naidoo, D.M. Ferguson. 1991 Tenderizing, aging, and thawing effects on sensory, chemical, and physical properties of beef steaks. J. Food Sci. 56:1125.

Morgan, J. B. T.L. Wheeler, M. Koohmaraie, J.W. Savell and J.D. Crouse. 1993. Meat tenderness and the calpain proteolytic system in longissimus muscle of young bulls and steers. J. Anim. Sci. 71:1471.

Morgan, J.B., J.W. Savell, D.S. Hale, R.K. Miller, D.B. Griffin, H.R. Cross and S.D. Shackelford. 1991. National beef tenderness survey. J. Anim. Sci. 69:3274.

Mosely, W.M., L.F. Krabill and R.F. Olsen. 1982. Effect of bovine growth hormone administered in various patterns on nitrogen metabolism in the holstein steer. J. Anim. Sci. 55:1062.

NCA. 1994. National beef tenderness plant. National Cattlemen's Assct. Denver, CO.

Newman, J.A., T. Tennessen, A.K.W. Tong, G.H. Coulter, G.J. Mears and H. Doomenbal. 1990. Effects of zeranol implantation on growth, feed conversion, testicular development and behavioral traits of young bulls fed for slaughter. Can. J. Anim. Sci. 70:1005.

Nichols, W.T., D.P. Hutcheson, F.M. Byers, W.L. Nfies and T.R. Kasari. 1992. Effects of anabolic growth promotants on rate and composition of growth in finishing beef steers. J. Anim. Sci. 70 (Suppl. 1):210 (Abstr.).

Nute, G.R. and E. Dransfield. 1984. The quality of sirloin from zeranol implanted steers. J. Food Technol. 19:21.

O'Lamhna, M. and J.F. Roche. 1984. Recent studies with anabolic agents in steers and bulls. In: Roche, J.F. and D. O'Callaghan (Ed.). Manipulation of Growth in Farm Animals. p. 85. Martinus Nijhoff Publishers, Hingham, MA.

Olson, D.G., F.C. Parrish, W.R. Dayton and D.E. Goll. 1977. Effect of postmortem storage and calcium activated factor on the myofibrillar proteins of bovine skeletal muscle. J. Food Sci. 42:117.

Olson, D.G., F.C. Parrish and M.H. Stromer. 1976. Myofibril fragmentation and shear resistance of three bovine muscles during postmortem storage. J. Food Sci. 41:1036.

Parrish, F.C., R.B. Young, B.E. Miner and L.D. Anderson. 1973. Effect of postmortemconditions on certain chemical, morphological and organoleptic properties of bovine muscle. J. Food Sci. 38:690.

Parrish, F.C., R.E. Rust, G.R. Popenhagen and B.E. Miner. 1969. Effect of postmortem aging time and temperature on beef muscle attributes. J. Anim. Sci. 29:398.

Pearson, A.M., A.M. Wolzak and J.I. Gray. 1983. Possible role of muscle proteins in flavor and tenderness of meat. J. Food Biochem. 7:189.

Perry, T.C., D.G. Fox and D.H. Beermann. 1991. Effect of an implant of trenbolone acetate and estradiol on growth, feed efficiency and carcass composition of holstein and and beef steers. J. Anim. Sci. 69:4696.

Preston, R.L. and R.C. Herschler. 1992. Controlled release estradiol/progesterone anabolic implant in cattle. Texas Tech Univ. Agric. Sci. Tech. Rep. No. T-5-317:140.

Preston, R.L., S.J. Bartle, A.C. Brake and R.E. Castlebury. 1990. Effect of anabolic growth implants on the time required to reach quality grade equivalent to nonimplanted cattle. Texas Tech Univ. Agric. Sci. Tech. Rep. No. T-5-283:22.

Preston, R.L. 1987. Role of anabolic and repartitioning agents in the production of lean beef. Southwest Nutrition and Management Conference, p. 12.

Price, M.A., M. Makarechian, T. Tennessen and G.W. Mathison. 1983. The effects of zeranol on the feedlot performance of beef bulls. Can. J. Anim. Sci. 63:803.

Price, M.A. and T. Tennessen. 1981. Preslaughter management and dark-cutting in the carcasses of young bulls. Can. J. Anim. Sci. 61:205.

Prior, R.L., S.B. Smith, B.D. Schanbacher and H.J. Mersmann. 1983. Lipid metabolism in finishing bulls and steers implanted with oestradiol-17B-dipropionate. Anim. Prod. 37:81.

Pritchard, R.H., M.A. Robbins and D.H. Gee. 1992. Implant combinations and reimplanting strategies for yearling steers fed high concentrate diets. SDSU Agri. Exp. Sta. Beef Report: 92-7:24.

Pritchard, R.H., D.H. Gee and M.A. Robbins. 1990. Effects of estradiol-trenbolone acetate implant combinations on feedlot performance and carcass traits of two steers types. S. Dakota Beef Rep. 11:38.

Reid, J.F.S. 1983. Estradiol benzoate implants. In: Anabolics in Animal Production. (Ed. E. Meissonnier and J. Mitchell-Vigneron), pp 143-154. Offfice International des Epizooties, Paris.

Rico, A.G. and V.B. Sacaze. 1984. New data on metabolism of anabolic agents. In: Roche, J. F. and D. O'Callaghan (Ed.). Manipulation of Growth in Farm Animals. p. 72. Martinus Nijhoff Publishers, Hingham, MA.

Riley, J. and R. Pope. 1984. Single vs. reimplant programs for finishing steers. Kansas State University Cattlemen's Day 448:89. Kan. St. Univ., Manhattan.

Robbins, M.A., R.H. Pritchard and G.H. Gee. 1991. Effects of anabolic implants on feedlot performance and carcass characteristics of two steer phenotypes. J. Anim. Sci. 69:478.

Roche, J.F. 1983. The use of natural steroids, hormonal and xenobiotics. In; Anabolics in Animal Production. (Ed. E. Meissonnier and J. Mitchell-Vigneron), pp 119-127. Offfice International des Epizooties, Paris.

Rouse, G., B. Reiling, D. Maxwell, and D. Loy. 1990. Performance and carcass characteristics of steers and bulls implanted with combinations of Synovex and Finaplix. Iowa St. Beef/Sheep Rep., A.S. Leaflet 711:59.

Rumsey, T.S., A.C. Hammond and J.P. McMurtry. 1992. Response to reimplanting beef steers with estradiol benzoate and progesterone: performance, implant absorption pattern, and thyroxine status. J. Anim. Sci. 70:995.

Rust, S.R. and M.L. Schlegel. 1989. Effect of trenbolone acetate and estradiol benzoate-progesterone on feedlot performance and carcass characteristics of growing-finishing steers. J. Anim. Sci. 67(Suppl. 2):144 (Abstr.).

SAS. 1986. SAS Users Guide. SAS Institute, Inc., Cary, NC.

Savell, J.W. and H.R. Cross. 1988. The role of fat in the palatability of beef, pork, and lamb. In: National Research Council (Ed.). Designing Foods, p. 345. National Academy Press. Washington, D.C.

Savell, J. W., H.R. Cross and G. C. Smith. 1986. Percentage ether extractable fat and moisture content of beef longissimus muscle as related to USDA marbling score. J. Food Sci. 51:838.

Schanbacher, B.D. 1984. Manipulation of endogenous and exogenous hormones for red meat production. J. Anim. Sci. 59:1621.

Seideman, S.C., J.D. Crouse and H.R. Cross. 1985. The effect of sex condition and implanting on muscle fiber type characteristics. J. Anim. Sci. 61(Suppl. 1):93 (Abstr.).

Seideman, S.C. and P.R. Durland. 1983. Vacuum packaging of fresh beef review. J. Food Qual. 6:29.

Seideman, S.C. and P.R. Durland. 1983. The effect of cookery on muscle proteins and meat palatability: a review. J. Food Qual. 6:291.

Seideman, S.C., H.R. Cross, R.R. Oltjen and B.D. Schanbacher. 1982. Utilization of the intact male for red meat production: a review. J. Anim. Sci. 55:826.

Semiek, M.A. and M.L. Riley. 1974. Effect of post-slaughter aging on tenderness. J. Anim. Sci. 38 (Part 2):1328 (Abstr.).

Shackelford, S.D., M. Koohmaraie, L.V. Cundiff, K.E. Gregory, G.A. Rohrer, and J.W. Savell. 1994a. Heritabilities and phenotypic and genetic correlations for bovine postrigor calpastatin activity, intramuscular fat content, Warner-Bratzler shear force, retail product yield, and growth rate. J. Anim. Sci. 72:857.

Shackelford, S.D., M. Koohmaraie, T.L. Wheeler, L. V. Cundiff and M.E. Dikeman. 1994b. Effect of biological type on the incidence of the dark, firm, and dry condition in the longissimus muscle. J. Anim. Sci. 72:337

Shackelford, S.D., J.D. Crouse, J.W. Savell, H.R. Cross, B.D. Schanbacher and D.D. Johnson. 1992a. Performance and carcass characteristics of bulls as influenced by exogenous hormones. Meat Sci. 32:387.

Shackelford, S.D., J.W. Savell, J.D. Crouse, H.R. Cross, B.D. Schanbacher, D.D. Johnson and M.L. Anderson. 1992b. Palatability of beef from bulls administered exogenous hormones. Meat Sci. 32:397.

Shackelford, S.D., M. Koohmaraie, G. Whipple, T.L. Wheeler, M.F. Miller, J.D. Crouse and J.O. Reagan. 1991a. Predictors of beef tenderness: development and verification. J. Food Sci. 56:1130.

Shackelford, S.D., M. Koohmaraie, M.F. Miller, J.D. Crouse and J.O. Reagan. 1991b. An evaluation of tenderness of the longissimus muscle of Angus by Hereford versus Brahman crossbred heifers. J. Anim. Sci. 69:171.

Shackelford, S.D., M. Koohmaraie, G. Whipple, T.L. Wheeler, M.F. Miller, J.D. Crouse and J.O. Reagan. 1990. Prediction of tenderness of beef from the M. Longissimus after postmortem aging. J. Anim. Sci. 68(Suppl. 1):328(Abstr.)

Sharpe, P.M., N.B. Haynes and P.J. Buttery. 1986. Glucocorticoid status and growth. In: Buttery, P.J., D.B. Lindsay and N.B. Haynes (Ed.). Control and Manipulation of Animal Growth. p. 207. Butterworths, Boston.

Simms, D.D. and G.L. Kuhl. 1993. Sequential implanting with estradiol and trenbolone acetate containing implants in calf-fed Holstein steers. J. Anim. Sci. 71 (Suppl. 1):68 (Abstr.).

Sinnett-Smith, P.A. W. Dumelow, P.J. Buttery. 1983. Effects of trenbolone acetate and zeranol on protein metabolism in male castrate and female lambs. Br. J. Nutr. 50:225.

Smith, S.H., R.F. Plimpton, B.D. Van Stavem, N.A. Parrett and H.W. Ockerman. 1989. The effects of four implant treatments and two feeding systems on carcass and palatability characteristics of bulls. J. Anim. Sci. 67:2655.

Smith, G.C., G.R. Culp and Z.L. Carpenter. 1978. Postmortem aging of beef carcasses. J. Food Sci. 43:823.

Snochowski, M., K. Lundstrom, E. Dahlberg, J. Petersson and L.E. Edqvist. 1981. Androgen and glucocorticoid receptors in porcine skeletal muscle. J. Anim. Sci. 53:80.

Spencer, G.S.G. 1985. Hormonal systems regulating growth: A review. Livest. Prod. Sci. 12:31.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill Book Co., New York.

Stobbs, L.A., R.E. Grimson, D.N. Mowat, J.E. Richards, J.R. Nelson, H.H. Nicholson and R.P. Stilbom. 1988. Efficacy of compudose as an anabolic implant for growing-finishing steers. Can. J. Anim. Sci. 68:205.

Tarrant, P.V. 1987. Review: Muscle biology and biochemistry. Proc. Eur. Meeting of Meat Res. Workers. Helsinki, Finland. 1:1.

Trenkle, A. 1993. Protein requirement of cattle implanted with estradiol and trenbolone acetate. J. Anim. Sci. 71(Suppl. 1):260 (Abstr.).

Trenkle, A. 1991. The evaluation of Synovex S and combinations of Synovex S with Finaplix S in feedlot steers. Iowa St. Beef/Sheep Rep. A.S. R816:81. Ames, IA.

Trenkle, A.H. 1990. The evaluation of Synovex S, Synovex S-Finaplix S and Revalor S implant programs in feedlot steers. Iowa St. Beef/Sheep Rep. A.S. 606:56. Ames, IA.

Trenkle, A.H. 1985. The effect of compudose and finaplix implants alone and in combination on growth performance and carcass characteristics of feedlot steers. Iowa St. Beef/Sheep Rep. A.S. 553:123. Ames, IA.

Trenkle, A. and Topel, D.G. 1978. Relationships of some endocrine measurements to growth and carcass composition of cattle. J. Anim. Sci. 46:1604.

Unruh, J.A., D.G. Gray and M.E. Dikeman. 1986a. implanting young bulls with zeranol from birth to four slaughter ages: 1. Live measurements, behavior, masculinity and carcass characteristics. J. Anim. Sci. 62:279.

Unruh, J.A. D.G. Gray and M.E. Dikeman. 1986b. Implanting young bulls with zeranol from birth to four slaughter ages: II. Carcass quality, palatability and muscle-collagen characteristics. J. Anim. Sci. 62:388.

Unruh, J.A., C.D. Pelton, D.G. Gray, M.E. Dikeman, D.M. Allen and L.R. Corah. 1987. Effects of zeranol-implantation periods on palatability of longissimus steaks from young bulls and steers. J. Anim. Sci. 65:165.

USDA. 1989 Official United States standards for grades of carcass beef. AMS-USDA, Washington, D.C.

Van Wyk, J.J., L.E. Underwood, R.L. Hintz, D.R. Clemmons, S.J. Voina and R.P. Weaver. 1974. The somatomedins: a family of insulin-like hormones under growth hormone control. Recent Progress in Hormone Research. 30:259.

Vanderwert, W., P.J. Bechtel, D.L. DeVol, F.K. McKeith, L.L. Berger and R.D. Shanks. 1989. Factors related to longissimus tenderness among alternate methods of lean beef production. J. Food. Qual. 12:445.

Vanderwert, W., F.K. McKeith, P.J. Bechtel and L.L. Berger. 1986. Influence of zeranol implants and electrical stimulation on the palatability traits of five muscles in Angus and Limousin bulls and steers. J. Anim. Sci. 63:114.

Vanderwert, W., L.L. Berger, F.K. McKeith, R.D. Shanks, P.J. Bechtel. 1985a. Influence of zeranol implants on growth, carcass and palatability traits in bulls and late castrates. J. Anim. Sci. 61:537.

Vanderwert, W., L.L. Berger, F.K. McKeith, A.M. Baker, H.W. Gonyou and P.J. Bechtel. 1985b. Influence of zeranol implants on growth, behavior and carcass traits in angus and limousin bulls and steers. J. Anim. Sci. 61:310.

Van Vleck, L.D., A.F. Hakim, L.V. Cundiff, R.M. Koch, J.D. Crouse and K.G. Boldman. 1992. Estimated breeding values for meat characteristics of crossbred cattle with an animal model. J. Anim. Sci. 70:363.

Wagner, J.J. and R.H. Pritchard. 1992. Combination of Synovex-S and Finaplix-S for yearling steers. SDSU Agri. Exp. Sta. Beef Report: 92-8:29.

Wagner, J.F. and Veenhuizen, E.L. 1978. Growth performance, carcass deposition and plasma hormone levels in wether lambs when treated with growth hormone and thyroprotein. J. Anim. Sci. 47(Suppl. 1.):397(Abstr.).

Weekes, T.E.C. 1986. Insulin and growth. In: Ed. P. J. Buttery, D.B. Lindsay and N.B. Haynes. Control and Manipulation of Animal Growth. pp. 187. Butterworth's, London.

Wheeler, T.L., R.K. Miller, J.W. Savell and H.R. Cross. 1990a. Palatability of chilled and frozen beef steaks. J. Food Sci. 55:301.

Wheeler, T.L., J.W. Savell, H.R. Cross, D.K. Lunt and S.B. Smith. 1990b. Mechanisms associated with the variation in tenderness of meat from Brahman and Hereford cattle. J. Anim. Sci. 68:4206.

Wheeler, T.L., G.W. Davis, J.R. Clark, C.B. Ramsey and T.J. Rourke. 1989. Composition and palatability of early and late maturing beef breed-types. J. Anim. Sci. 67:142.

Whipple, G. M. Koohmaraie, M.E. Dikeman and J.D. Crouse. 1990a. Predicting beef-longissimus tenderness from various biochemical and histological muscle traits. J. Anim. Sci. 68:4193.

Whipple, G., M. Koohmaraie, M.E. Dikeman, J.D. Crouse, M.C. Hunt and R.D. Klemm. 1990b. Evaluation of attributes that affect longissimus muscle tenderness in *bos taurus* and *bos indicus* cattle. J. Anim. Sci. 68:2716.

Williams, S.E., D.D. Johnson, D.D. Hargrove, D.L. Wakeman. 1987. Palatability and carcass characteristics of Angus and Angus x Brahman steers when fed in different seasons, on different diets and slaughtered at two end points. J. Anim. Sci. 65 (Suppl. 1) :289 (Abstr.).

Wood, J.D., A.V. Fisher and Whelehan. 1986. The effects of a combined androgenic-oestrogenic anabolic agent in steers and bulls. Anim. Prod. 42:213.

APPENDIXES

APPENDIX A

CORRELATION TABLES

TABLE I

SIMPLE CORRELATION COEFFICIENT FOR CARCASS TRAITS AND WARNER-BRATZLER SHEAR FORCE VALUES, PROXIMATE ANALYSIS AND COOKING LOSSES

Item	Lipid %	Protein %	Ash %	Moisture %	WBS 7-day	WBS 14-day	WBS 21-day	Cook loss% 7-day	Cook loss% 14-day	Cook loss% 21-day
Days-on-feed	0.46**	0.06	-0.19**	-0.51**	0.10*	0.21**	0.25**	-0.18**	-0.12**	-0.08
Slaughter wt, kg	0.09*	0.34**	0.22**	0.41**	0.10*	0.12**	0.07	0.14**	0.16**	0.07
Carcass wt, kg	0.27**	0.41**	0.22**	0.25**	0.21**	0.29**	0.23**	0.04	0.15**	0.08
Skeletal maturity	0.10*	0.28**	0.17**	0.19**	0.11*	0.13*	0.15**	0.03	0.10*	0.13**
Lean maturity	0.05	0.27**	0.17**	0.23**	0.08	0.06**	0.10**	0.08	0.06	0.13
Overall maturity	0.08	0.30**	0.19**	0.23**	0.10*	0.10*	0.14**	0.06	0.09	0.14**
Marbling score	0.64*	-0.02	-0.15**	-0.06	-0.13**	-0.03	-0.04	0.03	0.07	0.02
Fat thickness, cm	0.33**	0.26**	0.11*	0.10*	0.08	0.18**	0.16**	0.01	0.07	0.04
Adjusted fat thickness, cm	0.36**	0.26**	0.09	0.08	0.09*	0.18**	0.18**	0.01	0.05	0.05
REA	-0.14**	0.39**	0.28**	0.40**	0.25**	0.21**	0.22**	0.11*	0.15*	0.17**
REA/cwt	-0.40**	0.05	0.13**	0.40**	0.08	-0.05	0.02	0.10*	0.03	0.01**
Yield Grade	0.42**	0.11**	-1.02	-0.07	-0.01	0.11**	0.08	-0.03	0.01	-0.03

* P < .05
**P < .01

TABLE II

ANOVA TABLE OF INDEPENDENT VARIABLES

Source	df
Weight Block (W)	3
Implant Treatment (I)	3
Days-Fed (D)	1
W x I	9
W x D	3
I x D	3
I x W x D	9
Residual	483

APPENDIX B

PERCENTAGE FIGURES OF TREATMENT GROUPS

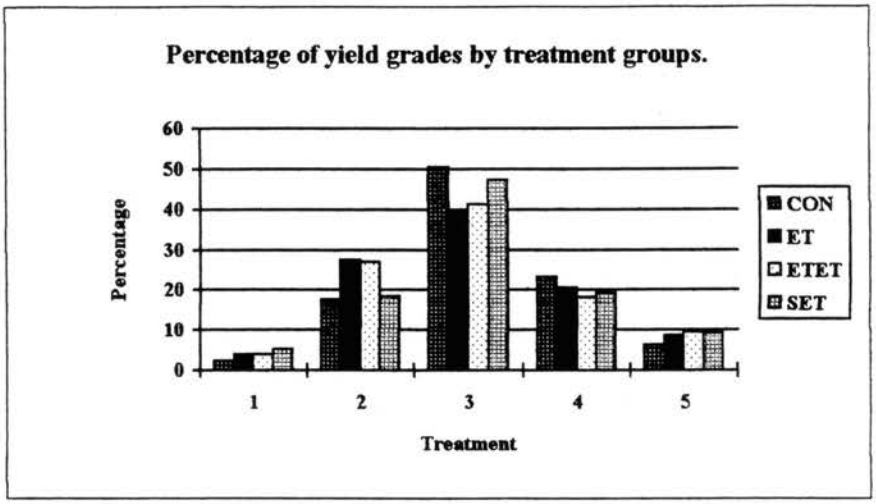


Figure 1. Percentages of yield grades by treatment groups.

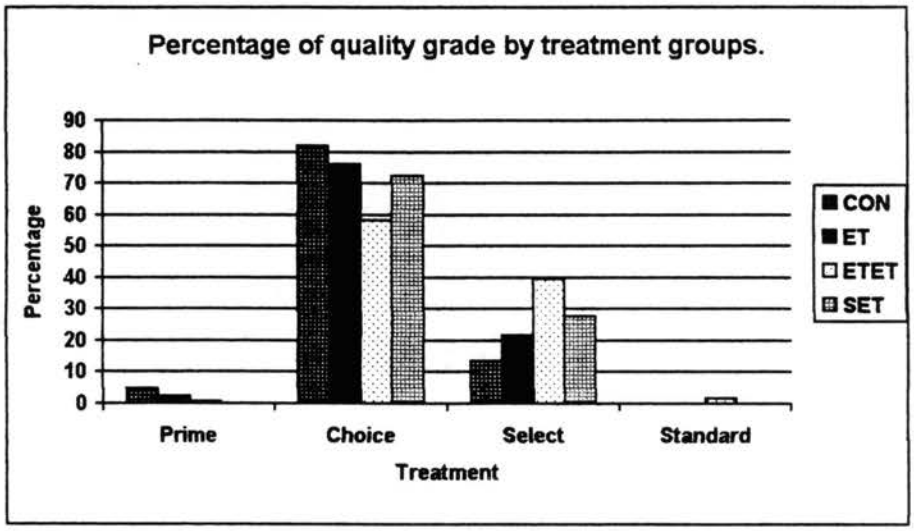
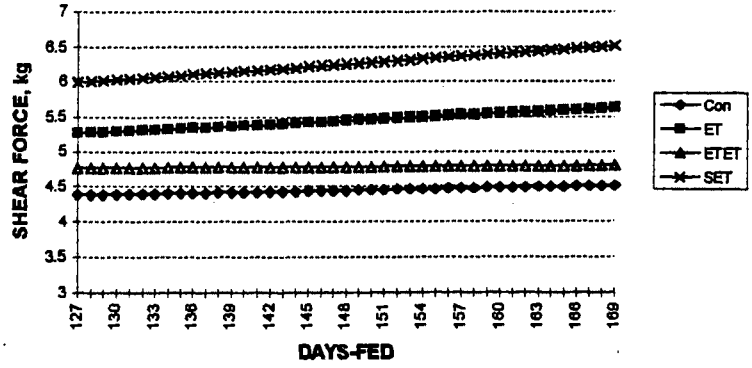
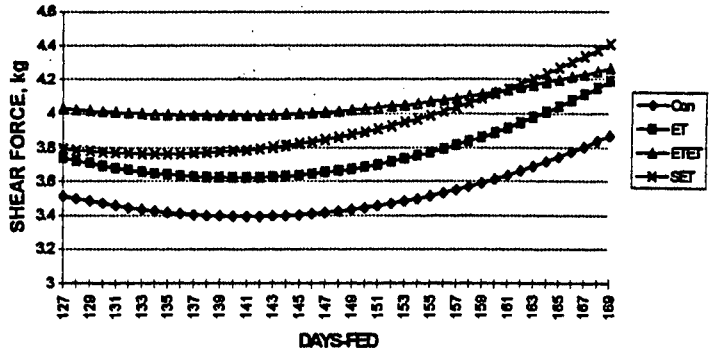


Figure 2. Percentage of quality grades by treatment groups.

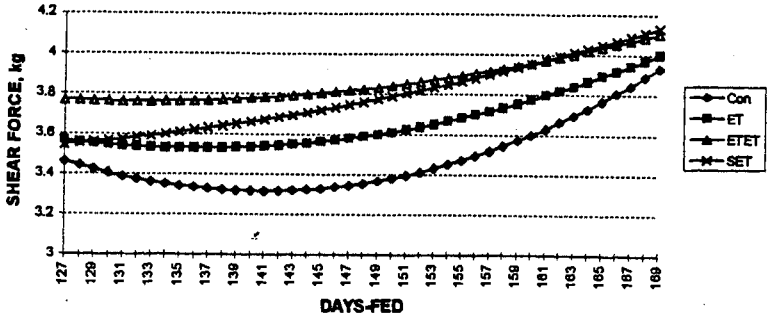
7-DAY SHEAR FORCE BY TREATMENTS



14-DAY SHEAR FORCE BY TREATMENTS



21-DAY SHEAR FORCE BY TREATMENTS



APPENDIX C

STATISTICAL DATA INFORMATION

SEPARATING MEANS (VARIANCES), CONSTRAST TO DETERMINE SIGNIFICANCE BETWEEN THE MEANS

1. AFTER USING PROC GLM ON SAS, DETERMINE IF LINEAR/QUADRATIC
2. $S^2\hat{y} = (S\, y_i^2 + d^2 S^2 b_i)$
3. From the GLM model output statement, use the Error Mean Square
   $S\, y_i^2$ = Error Mean Square
   d^2 = (Day deviation from 148 constant days)^2 [- or + from 148]
4. From the Procedure Regression model output statement, use Standard Error for DAY
   S^2_{bi} = Standard Error for DAY
5. Error Mean Square = $\frac{\hat{S}_1^2 + \hat{S}_2^2}{2}$
   High Significance Difference (HSD) = Q (K, er $_{df}$) $\sqrt{EMS/n}$ n= no./group
   k = treatment-1=3
   er_{df} = 2n-2
6. HSD for LINEAR REGRESSION
   S^2 = MSE = (148 - days to value)^2 X (SE)^2
   EMS = $\frac{S^2(1) + S^2(2)}{2}$
   Q statistic = (4, 499) = 3.63 from Studenized Table
   4 = treatments and 499 = n-1
   HSD calculated = 2.62 X $\sqrt{EMS/128}$ 128 = n = per treatment

Take difference of values you are separating the means:
   Value 1 - Value 2 = "Value"
   If "Value" > than HSD calculated, then SIGNIFICANT
   If "Value" < than HSD calculated, then NONSIGNIFICANT

7. HSD for QUADRATIC REGRESSION
   DAYS^2 from Regression output of SAS
   S^2 = MSE = (Day $_{dev}$)^2 X (SE Day)^2 + (Day $_{dev}$)^2 X (SE ^{2})^2

Then take differences as above for SIGNIFICANCE OR NS

REA	CONSTANT AT SLWT OF 1125			
TRT	INTERCEP	B1	DAY1	I*B1
1	12.35787	-0.00156	160.9	12.10687
2	11.55133	0.010156	133.3	12.90513
3	11.8544	0.010189	129.8	13.17693
4	11.76428	0.010019	131.2	13.07878

REA	CONSTANT AT MARB OF 459			
TRT	INTERCEP	B1	DAY1	I*B1
1	12.35787	-0.00156	125.2	12.16256
2	11.55133	0.010156	160.1	13.17731
3	11.8544	0.010189	168.9	13.57532
4	11.76428	0.010019	169	13.45749

REA	CONSTANT AT ADFATTK OF 0.6"			
TRT	INTERCEP	B1	DAY1	I*B1
1	12.35787	-0.00156	137.8	12.1429
2	11.55133	0.010156	131.9	12.89091
3	11.8544	0.010189	134.3	13.22278
4	11.76428	0.010019	134.4	13.11084

PDRESS	CONSTANT AT SLWT OF 1125			
TRT	INTERCEP	B1	DAY1	I*B1
1	59.61104	0.031363	160.9	64.65734
2	58.2459	0.039218	133.3	63.47366
3	60.23361	0.032734	129.8	64.48248
4	58.28604	0.041879	131.2	63.78057

PDRESS	CONSTANT AT MARB OF 459			
TRT	INTERCEP	B1	DAY1	I*B1
1	59.61104	0.031363	125.2	63.53768
2	58.2459	0.039218	160.1	64.52471
3	60.23361	0.032734	168.9	65.76238
4	58.28604	0.041879	169	65.36359

PDRESS	CONSTANT AT ADFATTK OF 0.6"			
TRT	INTERCEP	B1	DAY1	I*B1
1	59.61104	0.031363	137.8	63.93286
2	58.2459	0.039218	131.9	63.41876
3	60.23361	0.032734	134.3	64.62978
4	58.28604	0.041879	134.4	63.91458

MARB.XLS

MARB		CONSTANT=SLWT			MSE=	6959.792		
	TRTMT	SCORE	DAYS	SEDAY	148D-D^2	SE^2	SEDAY2	SEDAY2^2
	CON	508.34	160.9	12.6518303400	166.41	160.0688	0.04274337	0.001827
	ET	421.91	133.3	10.2100721000	216.09	104.2456	0.03447755	0.001189
	SET	416.54	131.2	8.5181613500	282.24	72.55907	0.02876913	0.000828
	ETET	393.69	129.8	10.0479168900	331.24	100.9606	0.03394552	0.001152
1) CON/ETET								
1st TRT	CON		MSE	148D-D^2	SE^2	SEDAY2	SEDAY2^2	S^2
	S^2		6959.792	166.41	160.0688	0.042743	0.001827	33597.15
2nd TRT	ETET							
	S^2		6959.792	331.24	100.9606	0.033946	0.0011523	40402.37
	EMS	36999.76						
	HSD	61.71647						
DIFFERENCES								
CON		508.37						
ETET		393.69						
DIFF		114.68		SIGNIF				
2) CON/SET								
1st TRT	CON		MSE	148D-D^2	SE^2	SEDAY2	SEDAY2^2	S^2
	S^2		6959.792	166.41	160.0688	0.042743	0.001827	33597.15
2nd TRT	SET							
	S^2		6959.792	282.24	72.55907	0.028769	0.0008277	27439.1
	EMS	30518.12						
	HSD	56.05064						
DIFFERENCES								
CON		508.37						
SET		416.54						
DIFF		91.83		SIGNIF				
3) ET/ETET								
1st TRT	ET		MSE	148D-D^2	SE^2	SEDAY2	SEDAY2^2	S^2
	S^2		6959.792	216.09	104.2456	0.034478	0.0011887	29486.47
2nd TRT	ETET							
	S^2		6959.792	331.24	100.9606	0.033946	0.0011523	40402.37
	EMS	34944.42						
	HSD	59.97781						
DIFFERENCES								
ET		421.91						
ETET		393.69						
DIFF		28.22		NS				

2

VITA

Emma Sandol Johnson

Candidate for the Degree of

Doctor of Philosophy

Thesis: EFFECTS OF COMBINATION ANDROGENIC AND ESTROGENIC ANABOLIC IMPLANTS ON CARCASS TRAITS AND SHEAR FORCE AT THREE POSTMORTEM AGING PERIODS FOR SERIALLY-SLAUGHTERED STEERS

Major Field: Food Science

Biographical:

Personal Data: Born in Lubbock, Texas, November 26, 1954, the daughter of Vernon Terry (Percy) and Zeola Frances Lovelace Johnson. Mother of Micah Lee Gwartney Johnson.

Education: Graduated from Lovington High School, Lovington, New Mexico, in May, 1972; received the Bachelor of Science Degree from West Texas State University, Canyon, Texas, in May, 1976; received the Master of Agriculture Degree from West Texas State University, Canyon, Texas, in August, 1983; completed requirements for the Doctor of Philosophy at Oklahoma State University, December, 1995.

Professional Experience: Red Meat Inspector, United States Department of Agriculture, Food and Safety Inspection Service, November 1975 to April 1978; Commodity Meat Grader, United States Department of Agriculture, Agricultural Marketing Service, Meat Grading and Certification Branch, April 1978 to May 1983; Graduate Teaching Assistant and Meat Lab Manager, West Texas State University, Canyon, Texas, August 1982 to May 1983; Assistant Professor, Animal Science Department, Oklahoma Panhandle State University, Goodwell, Oklahoma, August 1983 to December 1993; Owned and raised purebred Simmental and commercial cattle.

Professional Organizations: American Meat Science Association, American Society of Animal Science, Institute of Food Technologist, Oklahoma Food Technologists, Council for Agricultural Science and Technology, FASAS Alpha Zeta, Block and Bridle, Business and Professional Women.