EFFECT OF ANABOLIC IMPLANTS ON YEARLING FEEDLOT STEER PERFORMANCE, CARCASS GRADE TRAITS, SUBPRIMAL YIELDS AND MUSCLE PROPERTIES

By

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CHAPTER I

INTRODUCTION

Cattlemen are continually striving for methods to improve productivity. In terms of growth rate, feed efficiency and lean meat production, intact males or bullocks easily out-perform either steers or heifers, but unfortunately, are harder to manage and produce carcass which have lower quality grades, darker muscle color and more variable tenderness (Field, 1971; Seideman et al., 1982). Consequently, bullock production is extremely limited in the United States.

One means by which performance of feedlot steers can be improved is by replacing a portion of the endogenous growth promoting hormones that are lost with castration with the use of an exogenous supply. Early work by Dinusson et al. (1950) with heifers and by Andrews et al. (1954) with steers demonstrated the effectiveness of both estrogenic and androgenic implants for promoting growth. Since that time, anabolic implants have been used extensively in beef production, and it is estimated that over 90% of the fat cattle slaughtered annually in the United States have been treated with implants (NCA, 1989).

Until recently (1987), only estrogenic implants were approved for commercial use, but the approval of Trenbolone Acetate (TBA), an androgenic compound, may offer additional options for increasing cattle productivity. TBA has generated considerable interest among feedlot operators because it apparently promotes growth via a different mechanism than estrogenic compounds, therefore allowing synergistic effects when the two are combined.

Besides improving growth, anabolic implants may also have favorable effects on carcass composition. It is widely accepted that anabolic implants, both estrogenic and androgenic, promote growth primarily through increasing the rate of protein deposition; thus an increase in muscling is often observed with the use of anabolic implants. The benefits of implants relative to growth and composition are obvious; however, current consumer preferences and marketing methods still place considerable emphasis on meat quality. Unfortunately, this is an area that has been largely ignored in previous implant studies. Our knowledge of TBA on subsequent qualitative traits is particularly limited since it is a relatively new product in the United States.

The objectives of this research were: 1) to evaluate the effects of different implant programs involving varying levels of estradiol and trenbolone acetate on performance, carcass traits and longissimus muscle properties of yearling feedlot steers and 2) to examine possible differences occurring due to the time and frequency of implant administration during finishing.

CHAPTER II

REVIEW OF LITERATURE

Aspects of Anabolic Implants and Cattle Growth

Relationship of Commercial Compounds to Endogenous Sex Steroids

Commercial preparations of anabolic implants are very similar in structure to the naturally occurring endogenous sex hormones, estrogen, testosterone or progesterone. The basis for use of these hormones, especially in steers, is to replace or augment hormones in the animals body which are deficient (Roche, 1983). Typically, these exogenous hormones are impregnated in silastic rubber implants or compressed pellets made with lactose (Istasse et al., 1988). The implants are administered subdermally in the ear of an animal and then slowly release the exogenous hormone into the bloodstream.

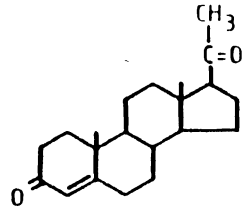
Currently, five hormonal compounds are cleared for use in the United States as growth promotants, three of which are classified as naturally occurring and two which are synthetic (NCA, 1989). In 1956, Synovex-S®, a combination of estradiol benzoate and progesterone was marketed to improve growth in steers and two years later, Synovex-H® (estradiol benzoate + testosterone proprionate), a compound designed specifically for heifers was introduced (Botts et al., 1986). Steer-Oid® and Heifer-Oid® are composed of the same active compounds as Synovex-S and Synovex-H, respectively. Estradiol 17ß

is the active compound in Compudose-200®, a long acting estrogenic implant(Mathison and Stobbs, 1983). Ralgro® contains resorcyclic acid lactone or zeranol, a plant estrogen, which is reduced from its parent compound zearalenone via fermentation (Fisher et al., 1986). The androgenic implant, Finaplix® contains trenbolone acetate, which is a synthetic analogue of testosterone but is thought to be much more active anabolically (Rico and Sacaze, 1984; Trenkle, 1987). The progestogenic compound Melengestrol Acetate (MGA) is another commercially used hormonal compound. Unlike the aforementioned products, MGA is administered orally and its main function is to suppress estrus in feedlot heifers (Patterson, et al., 1989); though it has been shown to improve feedlot performance (Bloss, et al., 1966).

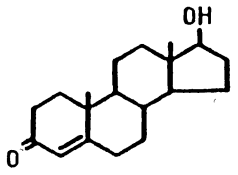
Chemical structures of the commercial compounds and parent hormones are illustrated in Figure 1. With the exception of zeranol, all of these hormones share the same basic 17 carbon, four ring structure characteristic of cholesterol. Differences in biological activity of endogenous steroids are due to differences in the quantity or location of double bonds in the rings, or the active groups at position 10, 13 or 17 carbons (Granner, 1985). Estradiol benzoate, MGA and testosterone proprionate are classified as natural hormones although they are not identical in structure to their endogenous parent compound. They are, however, readily converted into the endogenous form of the hormone and are metabolized through the same pathways (Botts et al., 1986). Zeranol and trenbolone acetate (TBA) exhibit activities similar to their respective parent compounds, but are not readily metabolized into the endogenous forms of estrogen and testosterone and hence are classified as xenobiotics (synthetic hormones).

FIGURE 1. Anabolic sex hormones: Grouping according to origin[a]

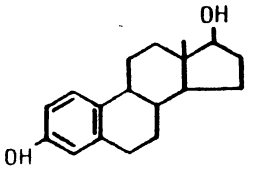
Endogenous sex hormones



Progesterone

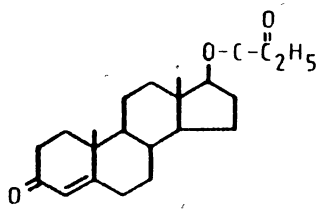


Testosterone

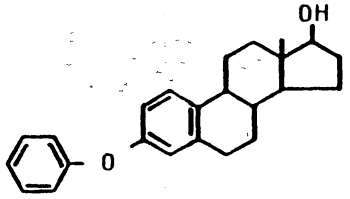


Estradiol 17ß

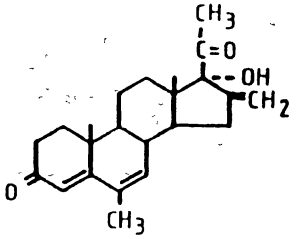
Steroidal sex hormones not occurring endogenously



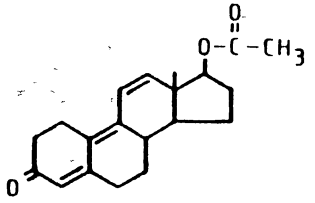
Testosterone proprionate



Estradiol benzoate

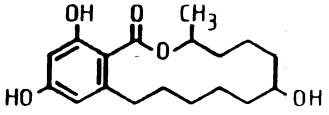


Melengestrol

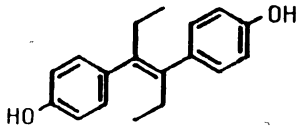


Trenbolone Acetate

Nonsteroidal compounds not occurring endogenously



Zeranol



Diethylstilbestrol

[a] Adapted from Rico and Sacaze (1984).

Mode of Action for Anabolic Compounds

Growth in farm animals can best be described as an increase in skeletal size and protein accretion. The numerous genetic, environmental and metabolic factors that regulate growth are varied and complex. The use of exogenous androgenic or estrogenic hormones to enhance growth in cattle is not a new concept. Burris et al.(1953) demonstrated that exogenous sources of testosterone in heifers and steers led to improvements in daily gain and feed efficiency. Likewise, Andrews et al. (1954) demonstrated that stilbestrol, an estrogenic compound, and a combination of stilbestrol and progesterone produced marked improvements in performance of finishing steers. It is widely accepted that these exogenous hormones improve growth in steers and heifers primarily through increased protein deposition (Griffiths, 1982; Keane and Drennan, 1987). Unfortunately, the exact mode of action by which estrogenic and androgenic hormones improve growth is only marginally understood.

Hormones Involved in Growth

It is unlikely that the effect of one single hormone determines changes in growth and body composition, but rather an alteration in overall hormone status or balance is responsible (Galbraith and Topps, 1981). Therefore, in order to understand the effects of either androgenic or estrogenic hormones on growth, a basic knowledge of some other hormones and the role they play in growth is essential. A review on the myriad of metabolic functions involved in growth are beyond the scope of this paper and discussion is limited to some of the very basic functions of hormones which have been shown to have direct implications on animal growth.

Growth Hormone. Growth Hormone (GH) is probably the one single hormone with the largest effect on growth. GH is anabolic (Buttery and Sinnett-

Smith, 1984) and serves to coordinate metabolism so that nutrients are partitioned to allow protein deposition (Baumann, 1982; Buttery and Sinnett-Smith, 1984). Trenkle (1974) also suggested that GH is necessary for the uptake of amino acids by muscle and may be needed for DNA synthesis. Nitrogen retention in steers treated with bovine GH was higher than untreated steers (Mosely, et al., 1982); likewise Rosemberg et al. (1989) noted that GH administered to lambs increased total carcass protein by 9.2%. Numerous studies with pigs have shown that treatment with porcine GH increases growth rate, improves feed efficiency and increases leanness (Chung, et al., 1985; Campbell et al., 1989; Kanis et al., 1990).

More recently, it has been suggested that increased protein synthesis is not a direct effect of GH, but is mediated through somatomedins, small peptide hormones produced in the liver which are influenced by GH levels (Galbraith and Topps, 1981; Etherton and Kensinger, 1984). Somatomedins are believed to control most or all of the effects of GH on growth processes (Davis et al., 1984). Somatomedins are thought to promote cell growth (Van Wyk et al., 1974) and have insulin like activities on growth (Van Wyk et al., 1974; Galbraith and Topps, 1981) in that they stimulate the uptake of amino acids into muscles and promote oxidative metabolism of glucose. Increased plasma concentrations of somatomedins upon treatment with GH have been observed in sheep (Rosemberg et al., 1989) and pigs (Chung et al., 1985).

Insulin. Insulin is at the center of metabolic regulation and is involved in numerous metabolic functions. Included in these functions are the stimulation of uptake and incorporation of amino acids into muscle (Guidotti, 1972; Wool, 1972; Prior and Smith, 1982) and the inhibition of proteolysis (Chrystie et al., 1977; Prior and Smith, 1982). By stimulating the uptake of amino acids in muscle, insulin may also decrease protein breakdown since less would be available to the

liver where the bulk of proteolysis occurs (Trenkle, 1974; Goldberg et al., 1980). Insulin also stimulates lipogenesis and inhibits lypolysis. Because insulin is lipogenic and therefore partitions nutrients for fat deposition, Davis et al. (1984) suggest that insulin plays a secondary or supportive rather than direct role in protein growth; possibly through enhancing somatomedin secretion.

Thyroid Hormone. The role that thyroid hormone serves in growth is not thoroughly understood and reports are somewhat conflicting. When thyroprotein was fed to heifers at a level of .5 g/100 lb body weight, an eight percent decrease in total live weight gain was observed (Dinusson et al., 1950). Likewise, Ely et al. (1976) observed decreased gains in lambs fed thyroprotein. Interestingly, they also observed lower plasma urea nitrogen levels suggesting decreased protein breakdown, but attributed this to probable increased excretion of nitrogen in the urine. Average daily gain and feed efficiency were unchanged and carcass weight was slightly increased in lambs fed thyroxine (Rosemberg et al., 1989). Reineke et al. (1946) noted that pigs fed thyroprotein at a level of .05% of the ration suffered decreased gains, but pigs fed thyroprotein at .005 to .0075% of the diet were slightly faster gaining and more efficient than control pigs.

Thyroid hormone stimulates oxidative metabolism and anabolic functions (Davis et al., 1984). Goldberg et al. (1980) showed that thyroid hormone plays a dual role in stimulating the synthesis and degradation of protein as they observed a decrease in both protein synthesis and protein catabolism in thyroidectomized rats resulting in an overall decrease in growth. At high levels, thyroid hormone appears to have catabolic effects while at low levels it appears to stimulate growth. Goldberg et al. (1980) suggest that at low levels, thyroid hormone may be effective at enhancing growth by increasing the rate of protein synthesis beyond the rate of catabolism while at high levels the rate of protein degradation becomes far greater than synthesis and muscular atrophy will occur.

Probable Mode of Action for Estrogens

The exact mode by which exogenous estrogens promote growth has yet to be established. It is thought that estrogens increase growth by increasing the rate of protein synthesis (Trenkle, 1987). In a review of the biological action of estrogens in cattle and lambs, Preston (1975) cites several hypotheses on the possible mechanisms by which estrogens promote anabolism. Most of these mechanisms do not include a direct or tissue effect, but rather an indirect effect by altering the blood levels of some of the other hormones previously discussed.

Preston (1975) suggested that estrogens promote growth by causing a release of growth hormone releasing factors from the hypothalamus which leads to a subsequent increase in the release of GH. This theory seems very plausible since the action of GH, or somatomedins under direct control of GH, is to increase the rate of amino acid uptake in muscle and increase the rate of protein synthesis. The theory is further supported by the fact that increases in GH levels have been observed in cattle receiving estradiol (Trenkle, 1970; Gopinath and Kitts, 1984; Hayden et al., 1988). Buttery and Sinnett-Smith (1984) also cite similar results for the effects of zeranol administration on blood GH levels.

Insulin, like growth hormone, is conducive to amino acid uptake and protein synthesis. A possible mechanism by which estrogens increase growth rate is through increasing blood insulin levels. Several studies have noted an increase in blood insulin associated with the administration of estrogenic implants; for reviews see Preston (1975), Buttery et al. (1978) and Buttery and Sinnett-Smith (1984).

The relationship of estrogenic implants to blood levels of thyroid hormone have been implicated (Preston, 1975), but reports on this relationship are limited and somewhat inconsistent. Stilbestrol had no effect on plasma protein-bound iodine (PBI) in steers or heifers (Trenkle, 1970). Gopanith and Kitts (1981)

reported that zeranol implants decreased plasma T_4 (thyroxine) and T_3 (triiodothyronine) levels of thyroid hormone in steers while Khal et al. (1978) observed increased plasma T_4 in steers implanted with estradiol benzoate. Although thyroid hormone plays a major role in the growth process, it seems unlikely that estrogenic implants exert a direct effect on growth by manipulation of thyroid hormone levels.

More recently it has been suggested that estrogen might promote muscle growth directly at the tissue level. Meyer and Rapp (1985) identified estrogen receptors in bovine skeletal muscle. Although concentrations of these receptors were thought to be 1,000 times less than concentrations in uterine tissue (a target organ of estrogen), the estradiol receptors had identical properties. Sauerwein and Meyer (1989) found the concentration of estrogen and androgen receptors in muscle to be different at different anatomical locations and postulated that differences in allometric growth may result from direct effects of estrogen or androgen in muscle. More research is needed to document this theory since estradiol has previously shown limited effect on muscle cell growth in vivo (Roeder et al., 1986).

Probable Mode of Action for Androgens

As with estrogenic implants, the exact mode of action by which trenbolone acetate (TBA) promotes growth is not fully answered. Unlike estrogens, TBA is thought to increase muscle growth primarily by decreasing the rate of protein catabolism (Trenkle, 1987). It is also generally accepted that androgens exert their effects largely at the tissue level (Galbraith, 1980; Roche, 1983; Buttery and Sinnett-Smith, 1984).

TBA administration apparently has minimal effects on blood levels of other anabolic hormones. Galbraith (1980) reported no change in plasma levels

of growth hormone or insulin with TBA treatment in heifers and growth hormone levels were actually lower in steers implanted with TBA (Hayden et al., 1988). For a more complete review see Buttery and Sinnett-Smith (1984).

Studies of androgen receptors in skeletal muscle further support the proposed activity of TBA at the tissue level. Snochowski et al. (1981) identified androgen receptors in porcine skeletal muscle and also showed that the availability of free androgen receptors was lower in hams of fast gaining pigs compared to those that were slower growing. The affinity of androgen receptors for testosterone was further demonstrated by Sauerwein and Meyer (1989). The availability of free androgen receptors was lowest in muscles of the neck and shoulder of intact males, whereas, young calves, and even bulls castrated 24 h prior to slaughter had higher concentrations of free androgen receptors in the same muscle groups. It would stand to reason that these androgen receptors would have a high affinity for TBA, but further research needs to be conducted to document this relationship.

Implantation with TBA results in improved nitrogen balance. Galbraith (1980) observed decreased levels of plasma urea and serum albumin levels in heifers implanted with TBA. This was attributed to either decreased rate of protein breakdown or an increase in the rate of amino acid uptake in muscle. Griffiths (1982) reported significantly lower urinary nitrogen excretion and an overall improvement in protein balance of steers implanted with TBA.

Reductions in plasma levels of cortisol have been associated with TBA administration (Hayden et al., 1988; Jones et al., 1988). Cortisol typically has catabolic activities on muscle and is negatively correlated with rate of gain in steers (Trenkle and Topel, 1978). In addition to androgen receptors, Snochowski et al. (1981) also identified glucocorticoid receptors in porcine muscles and demonstrated that they were negatively correlated to plasma cortisol levels.

Therefore, there is a possibility that TBA may exhibit an indirect effect on muscle growth by altering cortisol levels.

The mode by which estrogenic and androgenic anabolic implants increase protein accretion and muscle growth is still largely unexplained. A combination of some, or all of the mechanisms discussed above, or an even more complex combination of factors may be involved. In any event, this is an area that needs to be investigated further. If the exact mechanism by which these anabolic compounds function to promote growth can be explained, it might give insight to the development of new, even more effective growth promoting compounds.

Effect on Rate and Efficiency of Growth

Perhaps the best illustration of the effects that steroid hormones have on cattle growth is the difference in performance between intact and castrate males. In extensive reviews of bullock production, Field (1971) and Seideman et al. (1982) noted significantly faster growth rates and more efficient feed utilization for bulls compared to steers. Results on the effects of endogenous estrogen on growth are more variable. Dinusson et al. (1950) reported that spaying heifers resulted in a decrease in total weight gain as well as less efficient feed utilization. Crouse et al. (1987) noted that ovariectomized heifers were similar in rate of gain, but slightly less efficient in feed conversion than intact heifers. Hamernik et al. (1985) reported that ovariectomy in heifers had no significant effect on gains or feed efficiency.

Estrogenic Implants

In the United States, exogenous estrogens have been used commercially for over 30 years to improve productivity in feedlot cattle. Dinusson et al. (1950) first noted that stilbestrol pellets implanted subcutaneously in the shoulder region of beef heifers increased rate of gain by 12% and also improved feed

efficiency. Early research documenting the effectiveness of estrogens in steers was conducted by Andrews et al. (1954) wherein they noted that 60 mg of stilbestrol resulted in a 10 to 13% increase in rate of gain and a 6 to 8% improvement in feed to gain ratios. They also observed that 120 mg of stilbestrol yielded even more favorable results with 18 to 20% and 8 to 12% improvements in rate of gain and feed efficiency, respectively. The use of diethylstilbestrol in livestock was eventually banned in 1979 (Breidenstein and Cannon, 1986).

Estradiol has also been established as an effective anabolic agent for cattle. Responses in gain and feed efficiency associated with estradiol are variable across implant studies, and appear to be highly dependent on sex of the animal as well as dosage level and the time frame and frequency of implant administration.

Since the level of endogenous steroids in bulls is near optimal for maximum growth (Schanbacher et al., 1984; Unruh, 1986), the magnitude of response to estrogenic implants tends to be small. Johnson et al. (1984) reported only 2.8 and 3.9% increases in carcass weight for bulls implanted with Synovex (20 mg estradiol benzoate) and Compudose (24 mg estradiol 17ß), respectively while Peters et al. (1988) obtained similar results with only a three percent increase in average daily gain for bulls implanted with 35 mg of estradiol 17ß. Response to estrogens in heifers is variable. Roche (1983) reported no significant improvements in gain or feed efficiency with estradiol or zeranol implantation and Stobbs et al. (1988) reported only 6.7 and 4.1% improvements ($P<.10$) in gain and feed efficiency, respectively for heifers implanted with Compudose. Although variable, response to estrogens is greatest in feedlot steers. Table 1 presents a summary of estrogenic implant trials for steers. Though daily gain increased as much as 27.1% with estradiol (Prior et al., 1978), a more reasonable

estimate would be between 10 and 15% while a 4 to 10% improvement in feed efficiency could be expected.

Androgenic Implants

As with estrogens, trenbolone acetate (TBA) elicits different responses in performance depending upon sex class. Because it is androgenic, TBA by itself has a very limited effect in bulls; however TBA is complementary to the hormone supply in heifers and consequently elicits a favorable growth response. Galbraith (1980) noted as much as a 23% increase in rate of gain for TBA implanted heifers while Henricks et al. (1982) also reported significantly higher gains with TBA. Crouse et al. (1987) reported a tendency for improved feed efficiency in TBA treated heifers. Reports on the effects of TBA alone on steer performance range from slightly adverse to very favorable (Table 2). Although the sum of these trials indicate that TBA elicits favorable responses in growth of steers, this effect would likely be somewhat less than could be expected from an estrogenic implant.

Estrogens and Androgens Combined

Crouse et al. (1987) suggested that maximum growth should be obtained in cattle with androgen levels of intact males and estrogen levels of intact females. Because the mode of action for estrogens and androgens (TBA) differs, combined administration of the two typically results in additive effects on performance (Trenkle, 1987).

Unlike an estrogen or TBA alone, a combination of the two may improve bull performance (Grandadam et al., 1975; Fisher et al., 1986a), but much greater responses are usually obtained with castrate males. Table 3 summarizes performance responses of feedlot steers to combined estrogen + TBA implant treatments. Interestingly, Hicks et al. (1985) noted less than 10% and 5%

TABLE 1. DAILY GAIN AND FEED EFFICIENCY OF STEERS IN RESPONSE TO ESTROGENIC ANABOLIC IMPLANTS

Implant Treatment[a]	Number of obs/trt	Slaughter endpoint	Daily gain response[b]	Feed/gain response[b,c]	Source
Synovex-S (1x)	40	120 d	+23.0%	-----	Khal et al., 1978
Synovex-S (1x)	110	510 kg	+27.1%	-----	Prior et al., 1978
Compudose (1x)	40	140 d	+15.0%	+6.7%	Mathison and Stobbs, 1983
Synovex-S (1x)	120	124 d	+12.2%	+6.8%	Cain et al., 1984
Synovex-S (2x)	120	124 d	+11.6%	+6.8%	Cain et al., 1984
Synovex-S (1X)	48	56 d	+13.3%	+2.6%	Eldin et al., 1984
			68d 109d		
Synovex-S (1x)	18	109 d	+16.8% 6.8%	-----	Schanbacher, 1984
Compudose (1x)	18	109 d	+18.4% 7.2%	-----	Schanbacher, 1984
Compudose (1x)	24	126 d	+4.3%	+1.0%	Hicks et al., 1985
Compudose (1x)	125	128 d	+11.4%	+7.4%	Trenkle, 1987
			84d 189d	84d 109d	
Synovex-S (1x)	16	189 d	+8.1% 29.2%	+6.2% 12.8%	Loy et al., 1988
Synovex-S (2x)	16	189 d	+8.1% 21.2%	+6.2% 2.1%	Loy et al., 1988

[a] Synovex-S = 20 mg estradiol benzoate + 200 mg progesterone; Compudose = 24 mg estradiol 17ß; 1x = 1 implant on test; 2x = 1 implant on test and 1 mid test.

[b] Percentage response in daily gain and feed efficiency are calculated based on differences between implanted and control treatments or are otherwise actual percentage values reported.

[c] + indicates a favorable response (decreased feed required per unit of gain).

TABLE 2. DAILY GAIN AND FEED EFFICIENCY OF STEERS IN RESPONSE TO TRENBOLONE ACETATE (TBA)

Level of TBA[a]	Number of obs/trt	Slaughter endpoint	Daily gain response[b]	Feed/gain response[b,c]	Source
140 mg (1x)	6	100 d	+12.7%	+9.1%	Heitzman et al., 1981
300 mg (1x)	187	100 d	+13.8%	-----	Roche, 1983
140 mg (1x)	18	109 d	68d 109d +10.8% 1.8%	-----	Schanbacher, 1984
140 mg (1x)	24	126 d	-7.3%	-3.9%	Hicks et al., 1985
140 mg (2x)	125	128 d	+6.9%	+7.4%	Trenkle, 1987
140 mg (1x)	56	144 d	-3.1%	0.0%	Bartle et al., 1988

[a] 1x = 1 implant on test; 2x = 1 implant on test and 1 mid test.
[b] Percentage response in daily gain and feed efficiency are calculated based on differences between implanted and control treatments or are otherwise actual percentage values reported.
[c] + indicates a favorable response (decreased feed required per unit of gain).

TABLE 3. DAILY GAIN AND FEED EFFICIENCY OF STEERS IN RESPONSE TO ESTRADIOL (E2) OR ZERANOL (Z) IN COMBINATION WITH TRENBOLONE ACETATE (TBA)

Implant Treatment[a]	Number of obs/trt	Slaughter endpoint	Daily gain response[b]	Feed/gain response[b,c]	Source
36 mg Z+ 300 mg TBA (1x)	12	400 kg	+24.5%	+18.4%	Griffiths, 1982
45 mg E2 + 300 mg TBA	79	546 kg	+20.3%	-----	Roche, 1983
			68d 109d		
20 mg E2 + 140 mg TBA (1x)	18	109 d	+25.8% 11.1%	-----	Schanbacher, 1984
36 mg Z + 140 mg TBA (1x)	18	109 d	+21.7% 9.1%	-----	Schanbacher, 1984
24 mg E2 +:					
140 mg TBA (1x)	24	126 d	+8.6%	+4.6%	Hicks et al., 1985
140 mg TBA (2x)	24	126 d	+7.6%	+3.9%	Hicks et al., 1985
24 mg E2 +:					
140 mg TBA (1x)	125	128 d	+19.9%	+12.1%	Trenkle, 1987
140 mg TBA (2x)	125	128 d	+16.3%	+12.4%	Trenkle, 1987
16 mg E2 + 80 mg TBA (1x)	56	144 d	+23.2%	+10.8%	Bartle et al., 1988
28 mg E2 + 140 mg TBA (1x)	56	144 d	+27.4%	+13.8%	Bartle et al., 1988

[a] 1x = 1 implant on test; 2x = 1 implant on test and 1 mid test.
[b] Percentage response in daily gain and feed efficiency are calculated based on differences between implanted and control treatments or are otherwise actual percentage values reported.
[c] + indicates a favorable response (decreased feed required per unit of gain).

advantages in daily gain and feed efficiency, respectively. However, other studies indicate estrogen + TBA combinations may increase rate of gain by 15 to 25% while decreasing the quantity of feed required per unit of gain by 10 to 15%.

Anabolic implants tend to be most effective at promoting growth during the initial rather than the latter phase of finishing. Schanbacher (1984) observed a decrease in the relative advantages in growth of implanted animals during the latter half of the finishing period for each implant treatment. Similar results have occurred in trials with estradiol implants (Khal et al., 1978; Mathison and Stobbs, 1983) and with TBA in heifers (Henricks et al., 1982). In long term studies evaluating estradiol 17B, Utley et al. (1980) and Turner et al. (1981) both noted that growth was improved prior to, but not during finishing.

Much of this decrease in response is attributable to a probable decrease in the level of active hormone released from the implant. Henricks et al. (1982) observed a substantial rise in blood trenbolone levels of heifers shortly after TBA implantation followed by a gradual and rather large decline over the course of the feeding period. Similar results were obtained for plasma estradiol levels in Synovex implanted calves (Castree et al., 1988). Impetus shifts from muscle growth to fat deposition as an animal matures physiologically. It is the authors opinion that since implants exert their effect on growth via protein metabolism, a decrease in effectiveness during the latter part of finishing may in part be due to differences that occur in the relative proportion of muscle and fat deposition.

With the exception of Compudose, commercially available implants have an active payout period of around 60 to 80 days and maximum growth is not likely to be achieved with just one implant. Reimplanting with estrogenic implants has been shown to increase subsequent growth (Wagner, 1976; Owens et al., 1980). Hicks et al. (1985) and Trenkle (1987), however reported no additional response with reimplants of TBA.

Effect of Anabolic Steroids on Carcass Traits

Endogenous Sex Steroids

Endogenous testosterone has a considerable effect on carcass composition and quality attributes. In extensive reviews of intact male production, Field (1971) and Seideman et al. (1982) noted that bullocks produced carcasses with less fat and more muscling than steers. Unfortunately, bullock carcasses had darker muscle colors, lower marbling scores and quality grades and were more variable in tenderness. On the other hand, endogenous estrogen may function to hasten the onset of fattening in cattle as indicated by compositional differences between steers and heifers (Mukhoty and Berg, 1971; Bradely et al., 1966; Breidenstein et al., 1963). Mukhoty and Berg (1971) noted similar growth coefficients for muscle between steers and heifers and neither Breidenstein et al. (1963) nor Bradley et al. (1966) observed differences in m. longissimus area at an equal carcass weight; thus indicating that endogenous estrogen does not decrease muscle growth. Adams and Arthaud (1963) and Bradley et al. (1966) reported no differences in tenderness of steaks from steers and heifers.

Exogenous Sex Steroids

Sex. The effect that exogenous anabolic hormones have on carcass parameters is dependent somewhat upon sex. In bulls, administration of estrogenic compounds typically results in increased subcutaneous (s.c.) fatness but has minimal effect on muscling (Johnson et al., 1983; Johnson et al., 1984; Peters et al., 1988). Johnson et al. (1984) did not note any significant differences in tenderness or eating quality however.

Both estrogenic and androgenic implants tend to give similar responses for live performance in steers and heifers, and likewise they share similar effects

on carcass traits in both sexes. Because of compositional differences between steers and heifers, one might expect exogenous estrogen to hasten fattening, however this is not the case. Between sexes, there are likely inherent differences other than steroid hormones that dictate development of various tissues. Also, it is possible that estrogen elicits different responses at extremely high concentrations as with implanted cattle than it does at normal levels.

In a study involving ten different trials and over 400 animals (steers and heifers), Clegg and Cole (1954) observed the following effects for stilbestrol: 1. coarser textured, darker colored meat, 2. lower marbling scores and quality grades, 3. less external and internal fat, 4. heavier shoulders and rounds and 5. conformation more like that of a stag. Burris et al. (1953) also noted an increase in ribeye size and proportional weight of the round, but no effect on quality grade with testosterone treated steers and heifers alike. Since current estrogenic (estradiol and zeranol) and androgenic (TBA) implants differ from those used initially, these results are not always applicable to compounds which are presently used.

Effects on Composition

Typically, dressing percentage is not altered (Utley et al., 1980; Hicks et al., 1985; Loy et al., 1988; Stobbs et al., 1988; Trenkle, 1990) or is slightly increased with the use of anabolic implants (Mathison and Stobbs, 1983; Cain et al., 1984; Clancy et al., 1986; Crouse et al., 1987). Thus the increase in live weight gains observed with implants in many trials results in heavier carcass weights.

Muscling. Interestingly, several studies have indicated no significant effect on composition due to implantation (Mathison and Stobbs, 1983; Kercher et al., 1984; Hicks et al., 1985); however an increase in muscling is often observed. Increased longissimus muscle size has been associated with estrogenic (Owens et

al., 1980; Trenkle, 1985; Stobbs et al., 1988) and TBA implants alone (Trenkle, 1985; Crouse et al., 1987) and a combination of the two (Trenkle, 1985; Grant et al., 1988). Trenkle (1987) also observed larger longissimus muscle areas for steers receiving a combination of estradiol and TBA than for either compound alone. Delaney et al. (1984) observed a 17% increase in empty body protein with estrogenic implants. Similar results were obtained by Loy et al. (1988).

Limited data are available on the effect of implants on relative proportion of muscle. Griffiths (1982) and Wood et al. (1986) noted an increase in the relative proportion of neck and shoulder in estrogen + TBA treated steers. Keane and Drennan (1987) noted that estrogen + TBA implantation decreased the relative proportion of shank, inside round, knuckle, rump and fillet while it increase the proportion of shoulder, brisket and neck as well as overall proportion of lean. These three studies indicate that TBA may slightly alter muscle distribution to resemble that of bulls. Forrest (1978) noted that an estrogenic implant alone increased the proportion of total lean with significant increases in the hind, rear shank and rump regions and significant decreases in the belly and rib. It is evident that implants increase the overall proportion of lean in carcasses, but more research is needed to determine their effect, if any, on the distribution of lean.

Fatness. Limited studies exist that suggest anabolic implants reduce carcass fatness. Estrogenic implants have been shown to reduce s.c. fatness in steers (Johnson et al., 1983) and heifers (Stobbs et al., 1988) while TBA has been shown to decrease s.c. fat in heifers (Crouse et al., 1987). Likewise, administration of anabolic compounds has resulted in decreased levels of internal (perinephric) fat (Prior et al., 1978; Owens et al., 1980; Johnson et al., 1983).

A single measurement such as 12th rib s.c. fat or a subjective measurement such as internal fat are limited in their ability to assess true carcass fatness. Limited studies in which carcasses have been further fabricated and trimmed or physically dissected may provide stronger conclusions concerning anabolic implant effects on fatness. Fat as a proportion of total carcass weight decreases with implantation in steers or heifers (Forrest, 1978; Griffiths, 1982; Wood et al., 1986; Keane and Drennan, 1987). Only Wood et al. (1986) looked at the effects of implants on the relative differences in fat between various depots and they found no differences. They also compared steers to bulls and noted that bulls had a higher proportion intermuscular fat and a lower proportion of subcutaneous fat than steers, but when adjusted to a constant body fat ratio, no differences in relative proportions of fat depots were noted. They suggested that animals which are less developed in body fat will have a higher proportion of total fat in earlier maturing depots. It is likely that implants may function in a similar manner in that they do not alter rate of deposition between depots, but rather delay the onset of fattening overall.

Effects on Meat Quality

Marbling and quality grade. Since implants have been associated with decreased carcass fatness, and do not appear to have different effects on various fat depots (Wood et al., 1986) a concurrent decrease in intramuscular fat or marbling score might be expected. Limited studies with estrogenic implants have shown this result. Johnson et al. (1983) reported lower marbling scores for steers implanted with estradiol than for nonimplanted steers and Marchello et al. (1970) reported that diethylstilbestrol lowered marbling scores in steers and heifers. Cain et al. (1984) reported that steers receiving estradiol twice during finishing produced a lower percentage of choice carcasses than steers with no

implants or those receiving estradiol only at the onset of finishing. Most literature, however, indicates that estrogenic implants have very little effect on marbling or quality grade (Prior et al., 1978; Owens et al., 1980, Turner et al., 1981; Trenkle, 1987).

Since TBA was only recently introduced for commercial use, data concerning the effect of TBA on marbling and U.S. quality grade are very limited. Trenkle (1987) noted that marbling scores were lower for steers implanted with estradiol and TBA at the onset of finishing and TBA again in the latter half of finishing than for nonimplanted steers or those with unaccompanied estradiol implants. Hicks et al. (1985) and Kuhl et al. (1989) noticed a tendency for steers receiving TBA in addition to estradiol to produce fewer choice carcasses than steers receiving estradiol only; however differences were not large enough for statistical significance. Trenkle (1990) noted that steers receiving Revalor (140 mg TBA + 20 mg estradiol benzoate) twice during finishing produced significantly fewer choice carcasses than nonimplanted steers, however other implant combinations (Revalor on day 1 only or estradiol on day 1 + TBA late in finishing) did not significantly alter percentage choice. It appears that TBA may alter marbling and quality grade, and that time frame of TBA administration plays a role on this effect. Results, however are not yet consistent enough to draw strong conclusions.

Muscle Properties and Meat Tenderness. Perhaps one of the most important, but most neglected area of interest in evaluating the effect of anabolic implants is on specific properties of muscle. Crouse et al. (1987) observed increased moisture and decreased fat proportions in the soft tissue component of the 9th, 10th, 11th rib section of TBA implanted heifers. Similarly, Delaney et al. (1984) reported increased protein and decreased fat percentages in edible carcass tissue of steers implanted with estradiol. Rouse et al. (1990) observed no

significant difference in ether extract values of longissimus muscle samples from steers implanted with estradiol or estradiol + TBA compared to steers without implants.

Aside from initial work by Clegg and Cole (1954) which indicated an adverse effect by stilbestrol on lean color and texture, little work has been done in this area. In a general review of implant effects on carcass traits of steers and heifers, Cross and Belk (1989) reported no effect on lean color.

Research relating implants to meat tenderness is not conclusive. Johnson et al. (1983) observed increased shear force values with estradiol implants in steers. Conversely, TBA had no effect on shear force in heifers (Crouse et al. ,1987) and estradiol, or estradiol with TBA had no effect on shear force values or eating properties of longissimus muscle of steers (Trenkle, 1990).

Safety and Regulation of Anabolic Residues

Potential Health Risks and Concerns

Ever since the introduction of anabolic compounds to improve growth and efficiency of meat animals, there has been discussion on the public health risks from possible residues of these compounds in meat from treated animals. Concern centering around this topic has heightened lately because of the recent (January, 1989) ban on U.S. meat products enacted by the European Economic Community (EEC).

There are basically two areas of concern regarding anabolic residues in meat. The first concern is that these residues may be carcinogenic. Breidenstein and Cannon (1986) reported that diethylstilbestrol (DES) which was banned from use in livestock in 1979, was linked with an abnormally high incidence of a rare

cancer in daughters of women who had used DES during pregnancy to prevent miscarriage. Additionally, sex steroids at very high levels may have carcinogenic effects in laboratory animals (Huseby et al., 1980; Nagasawa et al., 1981). A second "fear" contends that residues of these sex steroids, via ingestion of meat from treated animals, may effectively interact with bodily hormones or may elicit physiological responses seen with high levels of corresponding endogenous hormones.

Actual Residue Levels and Their Implications

Research involving estradiol 17ß and zeranol (Parekh et al., 1983) or trenbolone acetate (Richold, 1983) demonstrates that these compounds, especially at normal levels, are not carcinogenic. Taylor (1983), Crawford (1988) and the World Health Organization (1988) all further support the view that proper use of anabolic implants in cattle production poses no threat to human health.

The "Delaney Clause" enacted by the FDA in 1958, based on the idea of "zero tolerance", was responsible for the demise of DES. Residues of DES at .5 and 2.0 parts per billion were found in beef liver, but none was ever detected in muscle (Breidenstein and Cannon, 1986). They estimated that women would have to consume 50 million pounds of beef liver for five consecutive days in order to achieve the same level of DES present in the "morning after" contraceptive used at that time.

Because of our increasing ability to detect residues at extremely minute levels, a policy more realistic than "zero tolerance" was necessary. The current "hormonal-no effect" policy states that ingestion of natural hormone residues at a level of 1.0% or below the daily production rate of that hormone in the most sensitive segment of the population (prepubertal children) poses no threat to

health (Farber and Arcos, 1983). The xenobiotic agents, trenbolone acetate and zeranol do not fall under this policy, but are deemed safe by the FDA (Crawford, 1988). As an illustration to put the residue issue into perspective, Crawford (1988) stated that 500 grams of beef from a treated animal would have 1,000, 1,5000, and several million times less estradiol than the average daily estradiol production in prepubertal boys, adult males and pregnant women, respectively.

Anabolic agents afford a more efficient means of red meat production, and at present, scientific evidence suggesting that proper use of these compounds poses any threat to human health is seemingly nonexistent.

CHAPTER III

TRENBOLONE ACETATE EFFECTS ON CARCASS TRAITS AND LONGISSIMUS MUSCLE PROPERTIES OF YEARLING FEEDLOT STEERS

ABSTRACT

Two trials of yearling steers were used to evaluate the effects of Trenbolone Acetate (TBA) at 140 mg, in combination with an estrogenic implant (Synovex-S with reimplants in Trial 1, n=291; Compudose in Trial 2, n=303) on carcass traits. Steers in each trial were randomized by phenotypic breed-type and assigned to one of four implant treatments (no TBA; TBA on d 0; TBA on d 70; TBA on d 0 and d 70). Steers were fed a high concentrate diet (Trial 1 = 139 d; Trial 2 = 134 d) and slaughtered. Following carcass data collection, 60 carcasses from each treatment in Trial 1 were selected randomly and ribeye rolls (IMPS 112A) were removed for cooking property and tenderness determinations. No differences ($P>.05$) were noted among treatments for carcass weight, subcutaneous fat thickness, percentage kidney, pelvic and heart fat, or marbling score. Carcasses from steers in the Trial 1 administered TBA implants early and late during finishing had larger ($P<.05$) longissimus muscle areas, more desirable USDA yield grades, more advanced lean maturity scores and darker longissimus muscle color scores than carcasses from steers without TBA. In both trials, carcass masculinity was slightly increased ($P<.05$) for late and doubly TBA

implanted steers. In Trial 1, the percentage of choice carcasses from doubly TBA implanted steers did not differ (P>.05) from controls (24.4 vs 33.4%). In Trial 2, the percentage of choice carcasses for late and doubly TBA implanted steers was lower (P<.05) than for controls (30.5, 31.0 vs 51.4%, respectively). No differences (P>.05) were observed for longissimus muscle composition, cooking properties or resistance to shear among treatment groups in Trial 1. Overall, TBA administered early in the feeding period had minimal effect on carcass traits while late administration of TBA tended to increase longissimus muscle area and reduce percentage choice.

(Key Words): Implants, Trenbolone Acetate, Steers, Carcass Traits.

Introduction

For over thirty years the cattle feeding industry has been using estrogenic anabolic implants to increase rate of gain and improve feed efficiency in finishing cattle. More recently, Trenbolone acetate (TBA), an androgenic compound, was approved for commercial use as an anabolic implant. TBA has generated considerable interest among feedlot operators because a combination of TBA with an estrogenic implant enhances growth beyond that of either compound alone (Roche, 1983; Schanbacher, 1984; Hicks et al., 1985; Trenkle, 1987; Kuhl et al., 1989).

Estradiol may increase muscling in steers (Forrest, 1978; Delaney et al., 1984; Trenkle, 1985), but has a minimal effect on quality grade (Mathison and Stobbs 1983; Delaney et al., 1984; Kercher et al., 1984; Hicks et al., 1985). Research comparing differences between estradiol and estradiol plus TBA on carcass composition and meat quality of steers is limited. Trenkle (1987) noted that

steers implanted with estradiol plus TBA at the onset of finishing and TBA again at mid-finishing produced carcasses with larger longissimus muscles and lower marbling scores than estradiol alone; however TBA alone at the onset of finishing did not alter carcass traits. Kuhl et al. (1989) and Hartman et al. (1989) likewise observed no difference in carcass traits between steers implanted with estradiol or with estradiol and TBA combined. The objectives of this study were to examine the effects of TBA combined with estradiol on carcass grade traits and longissimus muscle properties as well as possible differences due to the time frame and frequency of TBA administration.

Materials and Methods

Animals. Yearling steers were utilized in two separate implant trials at a commercial feedlot. Steers in Trial 1 (n=291; 288 kg) were randomized by apparent phenotypic breed-type into four classes: primarily Angus, primarily Hereford, primarily large European, and primarily Zebu for allocation to one of four implant treatments. Breed-type was utilized in this experiment to assure that the population of steers was similar across implant treatments; however this study was not intended to examine the effect of breed-type on carcass grade traits or longissimus muscle characteristics. Implant treatments were as follows: S-S = estradiol control steers with Synovex-S[1] (20 mg estradiol benzoate + 200 mg progesterone) on d 0 and again on d 70, ST-S = early TBA steers with Synovex-S + Finaplix-S[2] (140 mg TBA) on d 0 and Synovex-S on d 70, S-ST = late TBA steers with Synovex-S on d 0 and Synovex-S + 140 mg TBA on d 70, and ST-ST = double TBA steers with Synovex-S + 140 mg TBA on both d 0 and d 70

[1]Syntex Laboratories, Inc., Palo Alto, CA 94304
[2]Hoeschst-Roussel Agri-Vet Co., Somerville, NJ 08876

(Table 1). Trial 2 steers (n=303; 291 kg) were randomized in a similar fashion and assigned to one of four implant treatments (Table 2). Compudose-200[3] (24 mg estradiol 17ß) was administered on d 0 to steers across all treatments, but since Compudose is long acting (200 d), reimplants were not administered on d 70 as in Trial 1. TBA administration in Trial 2 followed a format identical to that outlined for Trial 1 (C = no TBA; CT= TBA on d 0; C-T=TBA on d 70; CT-T = TBA on d 0 and d 70). Steers were fed in two separate pens according to their respective trial with ad libitum access to a typical high energy finishing diet (NEm = 2.17 Mcal/kg; NEg = 1.42 Mcal/kg; crude protein = 12.5%). The finishing period lasted 139 d and 134 d for Trials 1 and 2, respectively.

TABLE 1. IMPLANT SCHEDULE FOR TRIAL 1

Implant period[b]	Treatment group[a]			
	S-S	ST-S	S-ST	ST-ST
On-test	Synovex-S (SYN)	SYN + TBA	SYN	SYN + TBA
Reimplant	SYN	SYN	SYN + TBA	SYN + TBA

[a] Implant treatments: S-S = Synovex-S on d 0 and d 70; ST-S = Synovex-S + Trenbolone acetate (TBA) on d 0, Synovex-S on d 70; S-ST = Synovex-S on d 0, Synovex-S + TBA on d 70; ST-ST = Synovex-S + TBA on d 0 and d 70.

[b] Implant periods: on-test = d 0 during processing; reimplant = d 70.

[3]Elanco Products Co., a division of Eli Lilly & Co., Indianapolis, IN 46285

TABLE 2. IMPLANT SCHEDULE FOR TRIAL 2

Implant period[b]	Treatment group[a]			
	C	CT	C-T	CT-T
On-test	Compudose (COMP)	COMP + TBA	COMP only	COMP + TBA
Reimplant	None	None	TBA	TBA

[a] Implant treatments: C = Compudose on d 0; CT = Compudose + Trenbolone acetate (TBA) on d 0; C-T = Compudose on d 0, TBA on d 70; CT-T = Compudose + TBA on d 0, TBA on d 70.

[b] Implant periods: on-test = d 0 during processing; reimplant = d 70.

Carcass data. Steers were slaughtered at a commercial facility and chilled at 0°C for approximately 24 h before complete USDA quality and yield grade data (USDA, 1987) were collected by an official USDA grader plus two experienced University personnel. In addition, all carcasses were subjectively scored for lean color (8 = pink; 7 = light cherry- red; 6 = cherry- red; 5 = slightly dark red; 4 = moderately dark red; 3 = dark red; 2 = very dark red; 1 = black) and masculinity characteristics (bullock score: 5 = no evidence of bullock tendencies; 4 = slight; 3 = moderate; 2 = severe; 1 = extreme). This bullock score reflects bulbo-cavernosus muscle, crus of the penis and forequarter musculature (m. splenius) development.

Longissimus samples. Sixty carcasses from each implant treatment in Trial 1 were randomly selected prior to grading for subsequent analysis of longissimus muscle (LM) chemical composition, cooking properties and resistance to shear. Approximately 48 h postmortem the ribeye roll, lip-on (IMPS 112A) was fabricated from the left side of each carcass (NAMP, 1986). Ribeye rolls were

vacuum packaged and shipped to the Oklahoma State University Meat Laboratory. Cooler aging at 2°C was standardized at 6 d for all ribeye rolls. The samples were subsequently frozen (-30°C) and faced (removal of uneven portion of the posterior end) before fabrication into steaks for compositional, cooking property and shear force determinations. A .65 cm thick LM sample for proximate analysis was removed from the posterior end of each ribeye roll, completely denuded of exterior fat and epimysial connective tissue and stored in Whirlpack® bags at -30°C. A 2.5 cm thick steak from each ribeye roll was removed immediately anterior to the proximate analysis sample, vacuum packaged and stored at -30°C.

Proximate Analysis. Proximate analysis of LM samples was performed in duplicate according to procedures outlined by AOAC (1984). Samples were immersed in liquid nitrogen and subsequently powdered in a Waring® Commercial Blendor (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. Following 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. Protein content was determined using the Kjeldal method. Pre-weighed (.5 g) powdered LM samples were placed in digestion tubes with two Kjel® tabs (3.5 g Potassium Sulfate + .0035 g Selenium) and digested for 2 h at 420°C. Samples were removed, extended with 70 to 80 ml of deionized H_2O and analyzed for protein using a KJELTEC® 1030 Auto Analyzer.

Cooking and Shear Force. Cooking property and shear force determinations were conducted in accordance with procedures outlined by the AMSA (1978). Shear steaks (2.5 cm thick) were thawed at 2°C for 24 h and weighed. Steaks were then broiled on Faberware® open hearth broilers to a final internal temperature of 70°C. Constantan coated copper thermocouples were placed in the geometric center of each steak and internal temperature was monitored using an OMEGA® OM-302 Temperature Logger. Cooking time to a medium degree of doneness (minutes/100 g raw steak) and cooking shrinkage (percentage weight loss) were calculated for each steak. After the steaks cooled to 25°C, six cores (1.27 cm diameter) were removed parallel to the longitudinal direction of the muscle fibers. Cores were singularly sheared using a Chatillon® Model SD-50 Warner-Bratzler shear apparatus to determine average kg of force required.

Statistical Analyses. Data were analyzed separately for each trial and the latter subset of proximate analysis and shear samples using the General Linear Models procedures of SAS (1986). One way classification analysis of variance (Steel and Torrie, 1980) was used with implant treatment as the main effect. All treatments were adjusted to a constant initial weight using a covariate since many carcass traits are highly weight dependent. Due to the use of a covariate, and because the number of observations was not equal across implant treatments (death loss etc.), the least squares means approach was used to determine statistical differences ($P<.05$).

Results and Discussion

Carcass Traits. Least squares means for Trial 1 carcass traits are presented in Table 3. The combination of TBA and estradiol apparently did not improve

growth beyond estradiol alone as carcass weight was unaffected (P>.05) by implant treatment. Subcutaneous fat thickness, percentage kidney, pelvic and heart fat (perinephric), and percentage of yield grade 4 carcasses were also unaffected by implant treatment (P>.05). Estrogenic implants have caused a slight reduction in s.c. fat (Johnson et al., 1983; Stobbs et al., 1988) and perinephric fat (Prior, 1978; Owens et al., 1980; Johnson et al., 1983). Additionally, Crouse et al. (1987) noted reduced s.c. fat thickness for carcasses from TBA treated heifers. However, beyond estradiol alone, added TBA may have limited effect on carcass fat measurements (Trenkle, 1985; Hartman et al., 1989; Kuhl et al., 1989).

Double TBA (ST-ST) carcasses had significantly (P<.05) larger longissimus muscle areas and more desirable yield grades than S-S or ST-T treatments. The increase in longissimus muscle area for double TBA implanted steers agrees with findings of Trenkle (1985, 1990) and Rouse et al. (1990). The lower numerical yield grades in ST-ST carcasses can be attributed to larger longissimus muscle areas since s.c. fat thickness, percentage kidney, pelvic and heart fat, and carcass weight were comparable across implant treatments.

Carcasses from double (ST-ST) or late TBA (S-ST) steers had slightly more advanced (P<.05) lean maturity scores than steers receiving no TBA (S-S). Likewise the ST-ST and S-ST carcasses had slightly darker (P<.05) lean color scores than S-S carcasses. It is important to note that lean maturity scores for all treatments in this study were well within the "A" maturity classification and lean color scores were likewise close to cherry-red. Fisher and Wood (1986) noted that bullock carcasses had longissimus muscles with higher pH values and darker colors than steers. Although TBA is androgenic, it does not appear to alter post-rigor muscle pH (Clancy et al., 1986). Marbling score and percentage choice in Trial 1 were not affected (P>.05) by implant treatment.

Compared to controls, masculinity traits in carcasses were enhanced slightly by late administration of TBA as noted by lower (P<.05) numerical bullock scores. Sauerwein and Meyer (1989) identified androgen receptors in bovine skeletal muscle and reported that concentrations of these free receptors was lowest in the neck and shoulder muscles of bulls. Griffiths (1982) and Wood et al. (1986) noted that the relative proportion of muscle in the neck and shoulder region increased in steers receiving TBA. These findings suggest that TBA may elicit testosterone-like effects on relative patterns of muscle growth.

Table 4 contains least squares means for carcass traits in Trial 2. Unlike results in Trial 1, longissimus muscle area and yield grade were not significantly (P>.05) altered by implant treatments with TBA. Carcass weight, s.c. fat thickness, percent kidney, pelvic and heart fat, and percentage yield grade 4 were also unaffected (P>.05) by implanting with TBA. Although well within the "A" maturity classification, skeletal maturity scores for carcasses from steers in the ST-S treatment were slightly more advanced (P<.05) than the other treatments. Lean maturity and lean color score were unaffected (P>.05) by implant treatment. As in Trial 1, administration of TBA twice during the finishing period resulted in carcasses with slightly more pronounced bullock traits than control steers (P<.05).

A noticeable difference between trials was the higher percentage of carcasses grading choice in Trial 2 (40.6 versus 32.6%). The mean marbling score for control (C) carcasses was slightly above 400 (small amount) and tended to be higher (P<.10) than marbling scores for double TBA (CT-T) carcasses. No statistical (P>.05) differences in marbling score were noted among the other treatments. Compared to controls, percentage choice was 19.6 and 26.4% lower for C-T and CT-T carcasses, respectively (P<.05). Results of other studies assessing TBA impact on marbling and quality grade are variable. Combined

TBA plus estrogen implant treatments have been reported to have no effect on marbling or quality grade (Trenkle, 1985; Hartman et al; 1989; Rouse et al., 1990). Trenkle (1987) reported that two TBA implants with estradiol lowered marbling score and quality grade compared to estradiol alone and in a later study (Trenkle, 1990), Revalor (estradiol + TBA) administered twice during finishing reduced percentage choice compared to estradiol administered once.

Any effect that TBA may exert on marbling or quality grade appears to be dependent on the time at which it is administered. Since reductions in marbling score and quality grade have been observed only when TBA is administered twice or late during finishing, implanting with TBA well before projected slaughter may minimize the possibility of quality grade reduction. More research is needed to determine if there is an optimum time frame for TBA administration.

Muscle Properties. Compositional data for LM samples from the subsample of ribeye rolls in Trial 1 are presented in Table 5. No effects (P>.05) were noted among treatment groups for percentage moisture, protein or ash. Lipid levels for S-S and ST-S LM samples were similar (3.70 and 3.80%) whereas values for S-ST and ST-ST samples were slightly lower (3.38 and 3.29%); however, differences were not significant (P>.05). Lipid values in this experiment are similar to the 3.4% mean reported by Savell et al. (1986) for longissimus muscles with slight marbling.

Table 6 illustrates cooking property and tenderness values for the subset of LM steaks from steers in Trial 1. Cooking time, cooking shrinkage and resistance to shear were unaffected (P>.05) by implant treatment. These results are consistent with data presented by Trenkle (1990). The percentage of tough steaks (shear values of 5.0 kg or higher) was more variable across implant

treatment; ST-ST and S-S steers had slightly higher values than ST-S or S-ST, but no differences (P>.05) were noted.

Implications

The larger longissimus muscle area observed with TBA added to estradiol in Trial 1 indicates that TBA may be an effective means of increasing muscle growth in feedlot steers, but results of this study indicate that TBA did not largely affect fat deposition. The alterations in carcass masculinity and lean color due to TBA in this experiment were small in magnitude and likely have no practical implications since all scores were well within an acceptable range.

Strictly from the standpoint of tenderness, the reduction in the percentage of carcasses grading choice with late or double TBA implantation is not likely to be detrimental. However, present grading standards and marketing strategies continue to dictate the need to produce cattle that will achieve a minimum marbling score of small in order to qualify for choice. The reduction in percentage choice observed in late and double TBA implant treatments, but not in the early TBA treatment suggests the possibility of an optimum slaughter time-frame when TBA is utilized during finishing. This slaughter window may depend upon the time span after TBA administration as well as a compositional endpoint. In order for the use of TBA to be profitable, both performance and carcass traits are important considerations in the development of this slaughter window.

TABLE 3. LEAST SQUARES MEANS FOR CARCASS GRADE TRAITS OF STEERS IMPLANTED WITH SYNOVEX-S OR SYNOVEX-S AND TRENBOLONE ACETATE

	Implant treatment[a]				
Item	S-S	ST-S	S-ST	ST-ST	SE
Number of steers	72	75	73	71	
Carcass weight, kg	313	316	314	315	2.59
Fat thickness, cm	1.36	1.31	1.36	1.18	.06
LM muscle area, cm^2	84.3^{f}	85.0^{f}	86.2^{fg}	88.8^{g}	1.15
Internal (KPH) fat, %	1.48	1.45	1.42	1.43	.03
Yield grade	2.6^{f}	2.5^{f}	2.5^{f}	2.2^{g}	.10
Skeletal maturity[b]	155	159	160	158	2.36
Lean maturity[b]	140^{fg}	141^{fg}	146^{gh}	150^{h}	2.21
Marbling score[c]	378	388	376	365	6.84
Percent yield grade 4	2.8	5.6	1.2	1.2	1.94
Percent choice	34.9	34.0	33.9	27.7	5.58
Lean color score[d]	6.1^{f}	6.0^{fg}	5.9^{gh}	5.9^{gh}	.06
Bullock score[e]	4.7^{f}	4.6^{f}	4.5^{fg}	4.3^{h}	.07

[a] Implant treatments: S-S = Synovex-S on d 0 and d 70; ST-S = Synovex-S + Trenbolone acetate (TBA) on d 0, Synovex-S on d 70; S-ST = Synovex-S on d 0, Synovex-S + TBA on d 70; ST-ST = Synovex-S + TBA on d 0 and d 70.

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

[c] Marbling score: 300 = "slight o" minimum for select; 400 = "small o" minimum for choice.

[d] Lean color score: 6 = cherry-red; 5 = slightly dark red.

[e] Bullock score: 5 = no evidence of bullock tendencies; 4 = slight evidence.

[fgh] Means in the same row with different superscript letters differ statistically ($P<.05$).

TABLE 4. LEAST SQUARES MEANS FOR CARCASS GRADE TRAITS OF STEERS IMPLANTED WITH COMPUDOSE OR COMPUDOSE AND TRENBOLONE ACETATE

	Implant treatment[a]				
Item	C	CT	C-T	CT-T	SE
Number of steers	75	78	73	77	
Carcass weight, kg	308	306	309	309	2.03
Fat thickness, cm	1.39	1.37	1.27	1.34	.05
LM muscle area, cm^2	81.5	82.2	84.1	83.1	1.04
Internal (KPH) fat, %	1.49	1.52	1.51	1.45	.04
Yield grade	2.7	2.6	2.5	2.6	.09
Skeletal maturity[b]	144^{f}	152^{g}	143^{f}	146^{f}	2.30
Lean maturity[b]	138	140	141	141	1.59
Marbling score[c]	408	399	388	380	8.25
Percent yield grade 4	2.9	2.5	1.3	2.5	1.76
Percent choice	54.6^{f}	44.6^{fg}	35.0^{gh}	28.2^{g}	5.57
Lean color score[d]	6.1	6.1	6.0	6.0	.05
Bullock score[e]	4.6^{f}	4.6^{f}	4.4^{g}	4.3^{g}	.07

[a] Implant treatments: C = Compudose on d 0; CT = Compudose + Trenbolone acetate (TBA) on d 0; C-T = Compudose on d 0, TBA on d 70; CT-T = Compudose + TBA on d 0, TBA on d 70.

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

[c] Marbling score: 300 = "slight 0" minimum for select; 400 = "small 0" minimum for choice.

[d] Lean color score: 6 = cherry-red; 5 = slightly dark red.

[e] Bullock score: 5 = no evidence of bullock tendencies; 4 = slight evidence.

[fgh] Means in the same row with different superscript letters differ statistically ($P<.05$).

TABLE 5. LEAST SQUARES MEANS FOR PROXIMATE ANALYSIS VALUES OF LONGISSIMUS MUSCLE FROM STEERS IMPLANTED WITH SYNOVEX-S OR SYNOVEX-S AND TRENBOLONE ACETATE

	Implant treatment[a]				
Item	S-S	ST-S	S-ST	ST-ST	SE
Number of samples[b]	59	60	58	59	
Moisture, %	73.25	73.13	73.32	73.48	.15
Extractable lipid, %	3.70	3.80	3.38	3.29	.17
Protein, %	21.91	21.88	21.97	22.09	.09
Ash, %	1.19	1.07	1.19	1.08	.09

[a] Implant treatments: S-S = Synovex-S on d 0 and d 70; ST-S = Synovex-S + Trenbolone acetate (TBA) on d 0, Synovex-S on d 70; S-ST = Synovex-S on d 0, Synovex-S + TBA on d 70; ST-ST = Synovex-S + TBA on d 0 and d 70.

[b] All comparisons were nonsignificant (P>.05).

TABLE 6. LEAST SQUARES MEANS FOR SHEAR FORCE VALUES AND COOKING PROPERTIES OF LONGISSIMUS MUSCLE FROM STEERS IMPLANTED WITH SYNOVEX-S OR SYNOVEX-S AND TRENBOLONE ACETATE

	Implant treatment[a]				
Item	S-S	ST-S	S-ST	ST-ST	SE
Number of steaks[b]	59	60	58	59	
Shear force, kg	4.7	4.5	4.6	4.8	.16
Tough steaks[c], %	32.2	22.6	25.2	40.4	6.00
Cooking time, min[d]	8.5	8.3	8.2	8.3	.22
Cooking shrinkage, %	32.6	31.4	31.7	32.0	.59

[a] Implant treatments: S-S = Synovex-S on d 0 and d 70; ST-S = Synovex-S + Trenbolone acetate (TBA) on d 0, Synovex-S on d 70; S-ST = Synovex-S d 0, Synovex-S + TBA on d 70; ST-ST = Synovex-S + TBA on d 0 and d 70.

[b] All comparisons were nonsignificant (P>.05).

[c] Tough steaks = steaks with shear force values over 5.0 kg.

[d] Cooking time calculated: (minutes to 70°C)/100 g raw steak).

CHAPTER IV

ANABOLIC IMPLANT EFFECTS ON STEER PERFORMANCE, CARCASS TRAITS, SUBPRIMAL YIELDS AND LONGISSIMUS MUSCLE PROPERTIES

ABSTRACT

One hundred forty crossbred yearling steers (353 kg) were blocked by weight and implanted as follows: (C) control-no implant; (S) Synovex-S (20 mg estradiol + 120 mg progesterone); (R) Revalor (20 mg estradiol + 140 mg TBA); (ST) Synovex-S + TBA; (STT) Synovex-S + TBA with TBA reimplanted d 58. Steers were slaughtered after 119 to 126 d on a finishing diet. The 9th-12th rib portion of the longissimus muscle was removed for post-rigor pH, proximate analysis and tenderness determinations. Following slaughter, left sides of 40 carcasses equally distributed across implant treatment and weight block were fabricated into boneless subprimals at three s.c. fat levels: untrimmed, 2.5 cm and .64 cm. Steers with estradiol and TBA combined (R; ST; STT) gained more rapidly ($P<.05$) than C or S steers. Likewise feed efficiency was improved ($P<.05$) with combined estradiol plus TBA. No differences were noted ($P>.05$) among treatments for carcass s.c. fat thickness, percentage kidney, pelvic and heart fat or lean color. Carcasses from steers receiving TBA (R, ST and STT) had larger ($P<.05$) m. longissimus areas and tended to have lower ($P<.10$) marbling scores and yield grades than C or S steers. Similar percentages (82-86%) of Choice carcasses were obtained across C, S and ST treatments; R steers were lower

(P<.05) with 51.8%. No differences (P>.05) were noted among treatments for post rigor pH, chemical composition, or cooking properties of m. longissimus. Shear force values for all steers with implants (S, R, ST and STT) tended to be higher (P<.10) than for controls. Implants increased (P<.05) subprimal and total side lean yield compared to controls; the largest increases of 2.3 and 2.8%, respectively occurred in steers receiving TBA plus estradiol. Corresponding decreases (P<.05) in percentage fat trim (.64 cm) were noted for the same treatments. Overall, estradiol plus TBA exhibited favorable effects on gain, efficiency, and composition; Revalor decreased quality grade.
(Key Words): Steers, Implants, Performance, Carcass Traits, Subprimals

Introduction

Anabolic implants are well established as an effective means for enhancing performance in feedlot steers. With the introduction of Trenbolone Acetate (TBA) into the United States in 1987, improvements in performance beyond traditional use of lone estrogenic implants may be realized. When TBA and estrogenic implants are combined they often have synergistic effects on growth (Griffiths, 1982; Schanbacher, 1984; Trenkle, 1987).

The benefits of improving rate and efficiency of growth through the use of anabolic implants are obvious, but with shifts in consumer preference towards leaner meat products, composition of growth has become equally important. Though their mechanisms may differ, both estrogenic and androgenic (TBA) implants improve growth primarily through increasing protein accretion (Buttery and Sinnett-Smith, 1984; Trenkle, 1987); several studies have shown an increase in muscling associated with anabolic implants (Forrest, 1978; Owens et al., 1980; Trenkle, 1985; Crouse et al., 1987; Loy et al., 1988).

Likewise, meat quality or palatability remains important. Several studies have shown estradiol to have minimal effects on marbling or quality grade (Prior et al., 1978; Owens et al., 1980; Turner et al., 1981), but in some cases, TBA in combination with an estrogen has reduced marbling or quality grade (Trenkle, 1987; Foutz et al., 1989; Trenkle, 1990). Research relating implant use to subsequent post rigor muscle characteristics such as color, pH, chemical composition and tenderness is limited.

The objectives of this study were to evaluate the effects of estradiol (Synovex-S) administered unaccompanied and in various combinations with TBA on steer growth, carcass traits and specific m. longissimus properties. Moreover, with boxed beef subprimals serving as the primary method of wholesale meat trade, subprimal yields were examined to more accurately determine the effects of implant treatment on carcass composition and ultimate value.

Materials and Methods

Animals. One hundred forty crossbred yearling steers averaging 353 kg, previously implanted with Compudose (24 mg estradiol 17ß) in August of 1988, were obtained from wheat pasture in late March. The steers were shipped approximately 160 kilometers to Oklahoma State University, individually weighed, tagged and processed. Because the steers were weighed upon arrival after being subjected to the stress of movement, trucking and fasting, initial weights were considered to be shrunk weights. Processing consisted of IBR-PI3, 4-way clostridia vaccination and deworming with Ivermectin. Steers were blocked into one of four different replications (n=35) based upon initial weight and assigned randomly to one of five different implant treatments: C = no

implant (Control); S = Synovex-S (20 mg estradiol benzoate + 200 mg progesterone) on d 1; R = Revalor[1] (20 mg estradiol benzoate + 140 mg trenbolone acetate) on d 1; ST = Synovex-S + Finaplix-S (140 mg trenbolone acetate) on d 1; and STT = Synovex-S + Finaplix-S on d 1 with a reimplant of Finaplix-S alone on d 58. Following implantation, steers in the same weight replication with common implant treatments (n = 7) were assigned to one of 20 different pens for feeding.

Each pen was equipped with a self feeder and all steers were started on an initial 50% concentrate diet which was increased stepwise (60, 70, 80, 90%) over a period of 15 d, to a final concentrate level of 95% in the finishing diet (Table 1). Individual live animal weights were obtained on d 30 of the trial and every 28 d thereafter. Feed consumption records for individual pens were recorded each weigh period. To compensate for fill, live weights taken throughout the feeding trial were shrunk by 4%. Steers from the two heavier weight replications were fed for 119 d and the two lighter replications were fed 126 d prior to slaughter to accommodate carcass data collection.

Carcass Data. On the day designated for slaughter, steers were transported approximately 400 kilometers and slaughtered within 2 h of arrival at a commercial packing plant. Carcasses were chilled at 0°C for approximately 24 h postmortem before complete yield and quality grade data (USDA, 1989) were recorded. Additionally, all carcasses were scored subjectively for lean color and masculinity characteristics (bullock score) using the following systems: lean color score of 8 = pink, 7 = very light cherry red, 6 = cherry red, 5 = slightly dark red, 4 = moderately dark red, 3 = dark red, 2 = very dark red, 1 = black; bullock

[1]Roussel Laboratories Ltd., Usiphar Groupe Roussel Uclaf, Paris; Under approval of the FDA, Revalor was used as an experimental compound; **Revalor is not approved for commercial use** at the time of this publication.

score of 5 = no evidence, 4 = slight, 3 = moderate, 2 = severe, 1 = extremely severe. Bullock scores reflected the development of the crus of the penis, bulbo-cavervosus muscle and musculature in the neck and shoulder regions.

M. Longissimus samples. Following collection of carcass data, a boneless portion of the wholesale rib (9th through 12th ribs) was fabricated from the left side of each carcass and vacuum packaged. Samples were cooler aged at 2°C for 7 d, subsequently frozen at -30°C, and faced (removal of dehydrated and uneven 12th rib end portion). For proximate analysis and pH determinations, a .64 cm thick slice was removed from the posterior (12th rib) end of the boneless ribs, completely denuded of exterior fat and epimysial connective tissue and stored in Whirlpack® plastic bags at -30°C. A 2.5 cm thick steak for cooking property and shear force determination was removed immediately anterior to proximate analysis slices from each boneless rib, vacuum packaged and stored at -30°C.

pH and Proximate analysis. Proximate analysis of longissimus muscle (LM) samples was performed in triplicate according to procedures outlined by AOAC (1984). Each sample was immersed in liquid nitrogen and subsequently powdered with a Waring® commercial blendor. Three grams of the powdered sample were placed on ashless filter paper, dried at 100°C for 24 h, desiccated for 1 h and re-weighed to determine moisture. Following moisture determination, each sample was placed in a soxhlet for 24 h for ether extraction of lipid followed by drying at 100°C for 12 h. Each sample was then desiccated and reweighed to calculate lipid content. The remaining portion of each sample was placed in a pre-weighed crucible and held at 650°C for 8 h before a final weight was recorded to determine ash content. Using the Kjeldahl method, protein content was determined from a separate .5 g powdered sample placed in a digestion tube

with two Kjeltabs® (3.5 g Potassium Sulfate +.0035 g Selenium) and digested for 2 h at 420°C. Samples were removed, extended with 70 to 80 ml of deionized H_2O and analyzed for protein using a KJELTEC® 1030 Auto Analyzer.

For pH analysis, duplicate 5 g LM samples were homogenized in 50 ml of deionized, distilled water for 30 s. A 5.0 pH buffer was used and temperature was standardized at 2 to 4°C. The measurement was taken after the sample was well mixed, and the pH meter had equilibrated (60 s).

Cooking and Shear Force. AMSA (1978) guidelines were followed for preparation of m. longissimus steaks. Shear steaks (2.5 cm thick) were thawed at 2°C for 24 h and weighed. Constantan coated copper thermocouples were placed in the geometric center of steaks to monitor internal temperature with an OMEGA® Temperature Logger. Steaks were then broiled on Faberware® open hearth broilers to a final internal temperature of 70°C (medium degree of doneness) and cooked weights were recorded. Cooking shrinkage was expressed as percentage weight loss for each steak whereas cooking time to a medium degree of doneness was expressed as minutes/100 g raw steak. After steaks cooled to 25°C, 6 cores (1.25 cm diameter) were removed parallel to the longitudinal orientation of the muscle fibers and individually sheared (Instron® Model 1122) one time to determine the average kg of force required for each steak.

Subprimal Fabrication. Two carcasses with weights closest to the mean of their respective pen were selected for a boxed beef cutout subsample. Carcasses in the subsample were equally distributed across weight replications and implant treatments, but were selected independent of quality and yield grade.

The left side of each carcass in the subsample was shipped to the Oklahoma State University Meat Laboratory for fabrication into boneless subprimals.

Prior to fabrication, chilled weight was obtained for all sides to account for cooler shrinkage. Sides were initially fabricated into the four major wholesale cuts (round, loin, rib and chuck) and further fabricated into 12 subprimals according to Institutional Meat Purchase Specifications (IMPS) outlined by NAMP (1988). The 12 subprimals reflected those used to determine boxed beef cutout value listed in the USDA National Carlot Meat Report (July 24, 1989). Weights were recorded for the untrimmed subprimals and at two s.c. fat trim levels (2.5 and .64 cm). Intermuscular fat in beef chucks (IMPS 115) was trimmed to approximately .64 cm along with s.c. fat. The minor wholesale cuts (foreshank, plate and flank) were fabricated into the various credit items reported in USDA National Carlot Meat Report. Ultimately, weights for 2.5 and .64 cm fat trim, total retail product (trimmed to .64 cm s.c. fat) and total bone were recorded for each side. Component percentages were calculated using aggregate side weight.

In an attempt to quantify the effect of muscle development, individual weight of the splenius (crest) muscle was recorded after fabrication of the chuck. Additionally, semitendinosus muscle (eye of round) weight was recorded to determine if implants affect muscle development differently at a posterior anatomical location.

Statistical Analyses. During the course of the trial, one steer from each of treatments S, R and ST suffered a broken leg. These steers were excluded from the data set and feed consumption records for their respective pens were adjusted according to net energy requirements for these steers. A 4 x 5 factorial arrangement of treatments (Steel and Torrie, 1980) was used with implant

treatment, weight replication, and the implant x weight interaction included in the model. All statistical analyses were conducted using the General Linear Models procedures of SAS (1986). Feed efficiency and calculated net energy determinations were computed using pen means for feed consumption because animals were not fed individually; daily gain, carcass traits and m. longissimus properties were analyzed on a per animal basis. Least squares means were utilized to account for the unequal number of steers among treatments in the overall data set. Data for the latter subset of carcasses for subprimal fabrication were analyzed separately. No interactions (P>.05) were apparent between implant treatment and weight replication. Single degree of freedom contrasts were conducted for the following effects: control versus all implants, control versus Synovex-S, control versus treatments with TBA, Synovex-S versus treatments including TBA, and early versus late TBA administration. Significance was reported at the .05 and .10 probability levels.

Results and Discussion

Performance Traits. Effects of implant treatment on cattle performance are presented in Table 2. Final weights were adjusted (hot carcass weight/.64, an assumed dressing percentage) for more accurate estimation of average daily gain, feed efficiency and estimation of net energy content of the diet. Steers receiving TBA plus estradiol either from Revalor (R) or combined implants of Synovex-S and Finaplix-S (ST and STT) were heavier at d 58 than S (P<.05) or C steers (P<.10). Likewise, final weight was higher (P<.05) for R, ST and STT compared to S or C at slaughter. In contrast to previous studies (Khal et al., 1978; Cain et al., 1984; Loy et al., 1988), Synovex-S did not increase mid-test or final weight above controls (P>.05). The combination of estradiol and TBA (R, ST, and

STT) increased (P<.05) overall average daily gains by an average of 6.2 and 11.6% respectively above C and S. This advantage in daily gain for TBA-estradiol implanted steers above nonimplanted steers is similar to 7 to 9% improvements noted by Hicks et al. (1985), but is considerably lower than increases of over 15% reported by Schanbacher (1984), Trenkle (1987) and Bartle et al. (1988). Interestingly, implants exhibited minimal effects on gains during the initial 30 d of finishing and tended to be most effective during the middle of the finishing period. Since all steers were implanted with Compudose, a 200 d implant, approximately 6 months prior to the beginning of the trial, residual effects of this implant may have been apparent during the initial phase of finishing thereby reducing the effects of the implants administered for finishing.

Numerical improvements in overall feed efficiency were 1.3, 4.4, 8.5, and 8.0% for treatments S, R, ST, and STT respectively, over controls. The most apparent improvement (P<.05) in feed efficiency occurred for steers receiving TBA-estradiol combined. Daily feed intake was similar across treatments except for steers treated with Synovex-S on day 0; they consumed less (P<.05) feed than controls or steers receiving TBA. Calculated NE_g values were highest (P<.05) for steers implanted with TBA (R, ST and STT) suggesting these steers used dietary energy most efficiently for live weight gain.

Carcass Traits. Values for the various carcass traits analyzed are represented in Table 3. As reflected in carcass adjusted final weight, TBA-estradiol (R, ST, STT) resulted in heavier (P<.05) carcasses than C or S. Adjusted s.c. fat thickness, percentage kidney, pelvic and heart fat, and marbling score were unaffected (P>.05) regardless of implant treatment. However, steers with TBA had larger (P<.05) longissimus muscle areas than C or S steers. This increase in longissimus muscle area agrees with earlier findings of Trenkle (1985 and 1990). A slight

improvement in yield grade was also noted for the combined TBA-estradiol steers over controls (P<.10).

Skeletal maturity scores for all steers receiving implants were slightly more advanced (P<.05) than maturity scores for control steers. Turner et al. (1981) reported more advanced overall maturity scores for steers receiving estradiol. It is possible that an exogenous source of estradiol may hasten skeletal development; however, since maturity scores for carcasses in all treatments were well within "A", these higher values are not likely to have any practical implications.

When partitioned on quality grade, the percentage of carcasses attaining choice status for steers implanted with Revalor was approximately 30% lower (P<.05) than for C, S and ST treatments which were all above 80%. Late TBA (STT) carcasses at 71.4% choice were not statistically (P>.05) different than the above mentioned group. Trenkle (1990) observed a 50% reduction (P<.05) in choice carcasses when steers were implanted with Revalor twice during finishing, yet singular Revalor implants at the onset of finishing did not significantly alter the number of carcasses attaining choice. In a previous study (Foutz et al., 1989), it was noted that TBA administered late or twice with estradiol during finishing reduced percentage choice compared to lone estradiol implants. It is apparent that TBA-estradiol combinations may alter quality grade. Additionally, dosage level, time frame and frequency of implant administration may serve a major role in this effect. The disparity between percentage choice for R and ST treatments further indicates that Revalor does not function the same as combined implants of Synovex-S and Finaplix-S.

No differences (P>.05) were noted across treatments for lean maturity or lean color scores. Likewise, no problems with "dark-cutting" beef were detected. In a

review, van Weerden (1984) observed that muscle color in veal calves was generally not affected by treatment with anabolics.

Steers receiving TBA either from Finaplix-S or Revalor produced carcasses with more masculine characteristics (lower numerical bullock scores) than non-implanted or Synovex-S implanted steers ($P<.05$). Additionally, bullock traits were most apparent with late administration (d 58) of TBA. Similar results were obtained in a previous study (Foutz et al., 1989). Again, the practical implications are minor for these slightly elevated bullock scores since the means for all treatments were between 4 (slight bullock tendencies) and 5 (no evidence).

M. Longissimus Properties. Values for post rigor longissimus muscle pH and proximate analysis are presented in Table 4. Estradiol and TBA apparently had no effect on post rigor muscle pH since all implant treatments were essentially equal at 5.7 and did not differ from controls ($P<.05$). Similar findings were reported by Clancy et al. (1986). Implant treatment did not significantly change chemical composition of LM samples, but there was a tendency for R and STT samples to have a lower lipid content than C or S samples. Rouse et al. (1990) reported no difference ($P>.05$) in LM ether extract values between steaks from steers implanted with estradiol or estradiol accompanied by TBA once or twice during finishing. In contrast to the present study, steers in the previously mentioned study were slaughtered at a compositional (.92 cm) rather than days fed endpoint. Both estrogenic and androgenic (TBA) anabolic implants promote growth primarily through increasing the rate of protein deposition but have a minimal direct effect on lipid metabolism (Buttery and Sinnet-Smith, 1984). Wood et al. (1986) suggested that while anabolic implants do not directly affect lipid metabolism, they may function to delay the onset of fattening. Because intramuscular fat is a late maturing depot, it may be less developed in implanted

versus nonimplanted animals after similar days on feed, but may be equally developed when overall composition is comparable.

Cooking time and cooking shrinkage of boneless rib steaks from implanted steers did not differ (P>.05) from the controls. Implanted steers produced steaks with slightly higher (P<.05) shear force values than non-implanted steers. Johnson et al. (1983) observed increased shear force values for steers implanted with estradiol while van Weerden (1984) reported slightly higher shear force values for LM steaks in veal calves treated with anabolics; other research, however, does not show an increase in LM shear values with TBA alone (Crouse et al., 1987) and estradiol alone or in combination with TBA (Trenkle, 1990). No differences among treatments were noted for percentage of tough (shear force values greater than 4.5 kg) steaks.

Subprimal Yields. Compositional traits of carcasses in the cutout subsample were similar to those of the overall data set (Table 6); therefore, cutout data for the subsample should accurately represent that which would have been obtained from the carcasses in the overall data set. Table 7 illustrates yields of the various subprimals expressed as a percentage of side weight. Yields exhibited a positive numerical response to implants in 34 of the 40 observations, but most differences were too slight for significance. Trimmed, boneless chuck (IMPS 115) yields were noticeably higher (P<.05) for TBA implanted (R, ST and STT) steers compared to control or S steers. Additionally, Striploin (IMPS 180) yields were significantly higher for implanted compared to nonimplanted steers. Overall, implants increased (P<.05) cumulative subprimal yields with the largest improvements occurring in combined estradiol-TBA treatments. Aside from chuck (IMPS 115) lean yields, data suggest that implant treatment had a minimal

effect on the relative distribution of lean between the other major carcass primals (round, loin and rib), but rather increased overall lean tissue growth.

Values for subprimal lean, total side lean, fat trim and side bone are presented in Table 8. An increase in muscling due to combined estradiol-TBA was observed. Steers receiving TBA produced more ($P<.05$) total subprimal and total lean (trimmed to .64 cm fat) than C or S steers. TBA with estradiol increased total lean yields by 2.8 and 2.4% above C and S, respectively. In previous work (Forrest et al. 1978), Synovex-S implanted steers yielded 3.8% more lean than nonimplanted steers; though Synovex-S tended to have a favorable response on lean yields in this study, the magnitude of response was much smaller. The significant increase in lean yields from combined TBA-estradiol treated steers is consistent with findings of Griffiths (1982) wherein a combination of the estrogenic compound zeranol plus TBA increased lean yields from 2.7 to 3.7%. Likewise, Fisher et al. (1986) noted that zeranol plus TBA resulted in slight improvements in lean yields. Reimplants of TBA on d 58 did not increase muscling beyond TBA with estradiol on d 1.

Fat trim was inversely related to lean yields with larger differences occurring at the .64 rather than 2.5 cm level. Although no differences were noted in s.c. fat thickness or percentage kidney, pelvic and heart fat at the carcass level for the subsample, estradiol-TBA carcasses produced fewer ($P<.05$) total pounds of fat at the .64 cm trim level than controls. Similar findings were reported by Griffiths (1982) wherein zeranol plus TBA reduced total carcass separable fat between 1.8 and 2.8% with a concomitant reduction in fat content of the edible portion of the carcass.

The method of fabrication in this study did not allow complete examination of relative differences in the partitioning of fat due to implant treatment, but interestingly, Southgate et al. (1988) observed a minor increase in

the proportion of s.c. fat with a decrease in the proportion of intermuscular, kidney and channel fat in steers receiving either estradiol or zeranol with TBA compared to nonimplanted steers. Since measurements for s.c. fat and percentage internal (KPH) fat were comparable at the carcass level, it might be inferred that intermuscular fat was the depot most affected by implantation. However, since percentage kidney, pelvic and heart fat is a subjective visual measurement and s.c. fat is based on a single measurement, this assumption would be difficult to defend without individual measurements for each of depot.

In addition to promoting muscle growth, anabolics implants may also affect skeletal growth, since changes in total bone weight with implants were relatively proportional to changes in total trimmed lean weight. When expressed as a percentage of total side weight, no significant differences were noted among treatments ($P>.05$) for the proportion of bone.

Development of the splenius (crest) muscle is illustrated in Table 9. Absolute weights for splenius muscle and chuck lean were heaviest ($P<.05$) for steers receiving TBA. Absolute weight alone is not a strong indicator of splenius development since it could reflect an increase in overall weight, however a slight increase in splenius development for TBA treated steers was detected when expressed as a percentage of chuck lean. Southgate et al. (1988) found that added TBA increased forequarter weight in steers beyond estradiol alone or no implant and similarly, Griffiths (1982) reported a higher proportion of lean meat in the forequarter of steers implanted with TBA plus zeranol over nonimplanted steers. The more masculine bullock scores assigned to carcasses from steers with TBA along with the development of the chuck and splenius muscle in the same treatments suggest that TBA may alter muscle distribution patterns of steers to be similar, though less dramatic to those seen in bulls.

Implications

The results of our study indicate that steers implanted with a combination of TBA and estradiol, managed under similar conditions, are faster gaining, more feed efficient, and more muscular than steers receiving no implant or lone estradiol implants. The increase in muscling was apparent both in ribeye area and lean yields. Additional implanting of TBA during finishing may not be profitable as reimplants of TBA on d 58 did not yield improvements in performance or muscling beyond TBA with estradiol on d 1 only. Implants did not significantly affect the longissimus muscle chemical composition and only increased shear force values slightly. However, Revalor or TBA administered late in the finishing phase may reduce the number of carcasses reaching the choice grade. A single implant of TBA with estradiol on d 0 was the most effective treatment in terms of improving both performance and carcass composition without negatively altering carcass qualitative traits.

Although not statistically partitioned, traditional whole carcass value and boxed beef value were determined for carcasses in the subsample using the July 24, 1989 National Carlot Meat Report prices. The use of implants increased boxed beef value per unit weight in this study despite lower percentages of choice in two treatments. This value increase was attributed primarily to increased subprimal yields. Attempts to relate the use of implants to end product value are limited and additional research is need in this area to strengthen predictions.

Since TBA was not evaluated as a single implant, it is difficult to determine the proportion of differences in traits specifically due to TBA. Although the dosage levels of TBA (140 mg) and estradiol (20 mg) are identical for Revalor and combined implants of Synovex-S and Finaplix-S except for the

progesterone in Synovex-S, steers in R and ST treatments did not exhibit the same response across all traits. Furthermore, Revalor, which is currently under consideration for approval as a commercial implant in the United States, may contain estradiol and trenbolone acetate at different levels than those used in this experiment and consequently may not elicit the same responses seen in this study.

TABLE 1. COMPOSITION OF FINISHING DIET, DRY MATTER BASIS

Feed	Percent concentrate					
	50	60	70	80	90	Final
Corn, whole, %	41.6	51.6	61.6	71.6	80.6	86.6
Cotton seed hulls, %	25.0	20.0	15.0	10.0	8.5	5.0
Alfalfa pellets, %	25.0	20.0	15.0	10.0	2.5	---
Supplement[a], %	8.4	8.4	8.4	8.4	8.4	8.4

Nutrients	Calculated analysis	
	Diet composition	Supplement composition
NE_m, mcal/kg	2.09	1.30
NE_g, mcal/kg	1.34	.84
Crude protein, %	12.3	48.4
NPN, % of diet	1.12	13.36
Crude fiber, %	5.37	9.37
Potassium, %	.55	2.06
Calcium, %	.45	5.06
Phosphorus, %	.33	.87

[a] Supplement composition: calcium carbonate 12.95%, cotton meal, solvent process 65.55%, potassium chloride 1.91%, Rumensin 60 units .26%, salt 3.57%, soymeal 44 10.47%, trace mineral .01%, Tylan 40 units .13%, urea 4.75%, vitamin A-30 units .26%, vitamin E 226,800 units .01%.

TABLE 2. LEAST SQUARES MEANS FOR LIVE STEER PERFORMANCE

	Treatment[a]						
	C	S	R	ST	STT	SE	Effect[b]
No of steers	28	27	27	27	28		
Weights, kg							
Initial	352	353	353	352	352	.52	
d 58	468	464	479	472	475	3.49	ct ST
Final[c]	532	524	541	544	547	3.82	CT ST
Gain, kg/d							
period 1[d]	1.68	1.58	1.85	1.74	1.78	.06	ST
period 2[e]	1.33	1.28	1.35	1.41	1.50	.06	ST
overall	1.47	1.39	1.53	1.56	1.59	.03	CT ST
Feed intake, kg/d							
period 1[d]	8.99	8.42	9.00	8.63	8.87	.18	CS st
period 2[e]	9.35	8.87	9.28	9.20	9.33	.15	CS ST
overall	9.04	8.46	9.01	8.79	8.98	.14	CS ST
Feed / Gain							
period 1[d]	5.38	5.32	4.87	5.00	4.97	.11	CI CT ST
period 2[e]	7.04	7.10	6.90	6.61	6.26	.25	
overall	6.15	6.07	5.88	5.63	5.66	.12	CI CT ST
Calculated net energy							
NE_g, mcal/kg	1.40	1.43	1.46	1.51	1.51	.02	CI CT ST

[a] Implant treatments: C = control (non-implanted); S = Synovex-S on d 1; R = Revalor on d 1; ST = Synovex-S + TBA on d 1; STT = Synovex-S + TBA on d 1 and TBA reimplanted on d 58.

[b] Contrast effects:
CS (P<.05), cs (P<.10) = control versus Synovex-S;
CI (P<.05), ci (P<.10) = control versus all implants;
CT (P<.05), ct (P<.10) = control versus treatments with TBA;
ST (P<.05), st (P<.10) = Synovex-S versus treatments with TBA.

[c] Final weight = hot carcass weight/.64.

[d] Period 1 = d 0 to d 58.

[e] Period 2 = d 59 to slaughter.

TABLE 3. LEAST SQUARES MEANS FOR CARCASS TRAITS

	Treatment[a]						
	C	S	R	ST	STT	SE	Effect[b]
No. of carcasses	28	27	27	27	28		
Carcass wt, kg	341	335	346	348	350	3.98	CT ST
Fat thickness, cm	1.49	1.54	1.34	1.39	1.44	.09	
LM area, cm^2	82.5	83.7	88.1	89.2	88.8	1.71	CI CT ST
KPH fat, %	2.1	2.0	2.1	2.1	2.0	.06	
Yield grade	3.2	3.1	2.8	2.8	2.8	.15	ct
Percent YG 4	7.1	14.2	0	7.7	10.7	6.66	
Maturity score [c]							
Skeletal	145	158	169	160	157	3.76	CI CT
Lean	139	139	138	140	139	1.92	
Marbling score[d]	463	435	418	447	438	14.7	
Percent Choice	82.1	82.1	51.8	85.7	71.4	7.87	
Lean color[e]	6.25	6.33	6.33	6.26	6.39	.09	
Bullock score[f]	4.6	4.6	4.3	4.4	4.1	.10	CT ST EL

[a] Implant treatments: C = control (non-implanted); S = Synovex-S on d 1; R = Revalor on d 1; ST = Synovex-S + TBA on d 1; STT = Synovex-S + TBA on d 1 and TBA reimplanted on d 58.

[b] Contrast effects:
CI (P<.05), ci (P<.10) = control versus all implants;
CT (P<.05), ct (P<.10) = control versus treatments with TBA;
ST (P<.05), st (P<.10) = Synovex-S versus treatments with TBA;
EL (P<.05), el (P<.10) = early versus late TBA administration.

[c] Maturity score: 100 to 199 = "A" maturity (approximately 9 to 30 months of age).

[d] Marbling score: 400 to 499 = "small" corresponding to choice.

[e] Lean color score: 7 = light cherry red; 6 = cherry red; 5 = slightly dark red.

[f] Bullock score: 5 = no evidence; 4 = slight bullock tendencies.

TABLE 4. LEAST SQUARES MEANS FOR LONGISSIMUS MUSCLE PROXIMATE ANALYSIS AND pH VALUES

	Treatment[a]					
	C	S	R	ST	STT	SE
No. of samples[b]	28	27	27	27	28	
Post rigor pH	5.7	5.7	5.7	5.7	5.7	.02
Moisture, %	72.5	72.9	73.2	72.8	72.9	.19
Protein, %	22.8	22.6	23.1	22.5	22.8	.18
Lipid, %	4.0	4.1	3.3	3.9	3.6	.26
Ash, %	1.1	1.1	1.1	1.1	1.1	.03

[a] Implant treatments: C = control (non-implanted); S = Synovex-S on d 1; R = Revalor on d 1; ST = Synovex-S + TBA on d 1; STT = Synovex-S + TBA on d 1 and TBA reimplanted on d 58.

[b] All means did not differ statistically (P>.05).

TABLE 5. LEAST SQUARES MEANS FOR LONGISSIMUS MUSCLE COOKING PROPERTIES AND SHEAR FORCE VALUES

	Treatment[a]						
	C	S	R	ST	STT	SE	Effect[b]
Number of steaks	28	27	27	27	28		
Cooking time[c]	7.6	7.2	7.9	7.4	7.2	.33	
Cooking shrink, %	29.1	30.0	28.9	30.0	29.5	.65	
Shear force, kg	4.00	4.43	4.32	4.12	4.41	.15	CS CI ct
Percent tough[d]	21.4	37.5	37.5	25.8	35.7	8.57	

[a] Implant treatments: C = control (non-implanted); S = Synovex-S on d 1; R = Revalor on d 1; ST = Synovex-S + TBA on d 1; STT = Synovex-S + TBA on d 1 and TBA reimplanted on d 58.

[b] Contrast effects:
CS (P<.05), cs (P<.10) = control versus Synovex-S;
CI (P<.05), ci (P<.10) = control versus all implants;
CT (P<.05), ct (P<.10) = control versus treatments with TBA;
ST (P<.05), st (P<.10) = Synovex-S versus treatments with TBA.

[c] Cooking time = minutes/100 g raw steak.

[d] Percentage of steaks with shear force values of 5 kg or higher.

TABLE 6. CARCASS COMPOSITIONAL TRAITS OF BOXED BEEF CUTOUT SUBSAMPLE

	Treatment[a]						
	C	S	R	ST	STT	SE	Effect[b]
No. of carcasses	8	8	8	8	8		
Carcass wt, kg	338	336	342	347	350	3.44	CT ST
Fat thickness, cm	1.60	1.63	1.37	1.32	1.60	.18	
LM area, cm^2	80.0	81.3	85.8	89.7	91.0	2.58	CT ST
KPH fat, %	2.3	2.1	1.9	2.2	2.0	.16	
Yield grade	3.4	3.3	2.8	2.7	2.9	.25	ci CT st

[a] Implant treatments: C = control (non-implanted); S = Synovex-S on d 1; R = Revalor on d 1; ST = Synovex-S + TBA on d 1; STT = Synovex-S + TBA on d 1 and TBA reimplanted on d 58.

[b] Contrast effects:
CI (P<.05), ci (P<.10) = control versus all implants;
CT (P<.05), ct (P<.10) = control versus treatments with TBA;
ST (P<.05), st (P<.10) = Synovex-S versus treatments with TBA;

TABLE 7. BONELESS, TRIMMED (.64 cm) SUBPRIMAL YIELDS EXPRESSED AS A PERCENTAGE OF CUMULATIVE SIDE WEIGHT

	Treatment[a]						
	C	S	R	ST	STT	SE	Effect[b]
No. of cuts	8	8	8	8	8		
112A Ribeye roll	2.91	2.83	2.94	3.05	3.02	.08	st
115 Bnls chuck	17.91	18.16	19.29	18.92	18.99	.36	CI CT ST
120 Brisket	2.61	2.66	2.40	2.86	2.56	.10	EL
167 Knuckle	2.51	2.72	2.48	2.71	2.64	.08	
168 Top round	4.96	5.11	5.22	5.16	5.08	.11	
170 Btm round	6.88	6.92	7.10	7.15	6.93	.13	
180 Striploin	3.00	3.12	3.37	3.22	3.18	.09	CI CT
184 Top sirloin	2.76	2.89	2.89	2.93	2.89	.10	
185 Btm sirloin[c]	1.87	1.79	2.07	1.98	1.78	.10	
189A Tenderloin	1.43	1.45	1.49	1.56	1.50	.04	ct
Total primal lean increase, %	----	+.81	+2.41	+2.70	+1.73	.71	CI CT st

[a] Implant treatments: C = control (non-implanted) S = Synovex-S on d 1; R = Revalor on d 1; ST = Synovex-S + TBA on d 1; STT = Synovex-S + TBA on d 1 and TBA reimplanted on d 58.

[b] Contrast effects:
CI (P<.05), ci (P<.10) = control versus all implants;
CT (P<.05), ct (P<.10) = control versus treatments with TBA;
ST (P<.05), st (P<.10) = Synovex-S versus treatments with TBA;
EL (P<.05), el (P<.10) = early versus late TBA administration.

[c] 185 Bottom sirloin represents the combination of 185A-flap, 185B-ball tip and 185C-triangle.

TABLE 8. SIDE BOXED BEEF LEAN, FAT TRIM AND BONE WEIGHTS AND PERCENTAGES

	Treatment[a]						
	C	S	R	ST	STT	SE	Effect[b]
No. of sides	8	8	8	8	8		
Primal lean, kg[c]	76.4	77.5	81.1	82.8	82.0	1.28	CI CT ST
Total lean, kg	102.6	102.9	108.5	110.9	109.8	1.71	CI CT ST
Fat trim							
2.5 cm, kg	25.6	24.2	22.3	22.6	24.5	1.26	
.64 cm, kg	39.7	37.4	34.3	37.4	37.2	1.90	ci CT
Side bone, kg	20.7	22.2	21.9	22.1	21.8	.56	CI ct
Primal lean, %	46.8	47.6	49.3	49.6	48.6	.71	CI CT st
Total lean, %	62.9	63.3	65.8	66.3	65.0	.89	CI CT ST
Fat trim							
2.54 cm, %	15.8	14.9	13.6	13.5	14.5	.75	ci CT
.64 cm, %	24.4	23.0	20.9	20.4	22.1	1.12	CI CT
Side bone, %	12.7	13.7	13.3	13.3	12.9	.34	

[a] Implant treatments: C = control (non-implanted); S = Synovex-S on d 1; R = Revalor on d 1; ST = Synovex-S + TBA on d 1; STT = Synovex-S + TBA on d 1 and TBA reimplanted on d 58.

[b] Contrast effects:
CI (P<.05), ci (P<.10) = Control versus all implants;
CT (P<.05), ct (P<.10) = Control versus treatments with TBA;
ST (P<.05), st (P<.10) = Synovex-S versus treatments with TBA.

[c] Primal lean consists of the 12 major boneless subprimals used to calculate boxed beef cutout value.

TABLE 9. SPLENIUS MUSCLE DEVELOPMENT

	Treatment[a]						
	C	S	R	ST	STT	SE	Effect[b]
No. of samples	8	8	8	8	8		
Splenius, kg[c]	.64	.73	.88	.81	.77	.05	CI CT
Chuck lean, kg	29.2	29.5	31.8	31.7	32.1	.62	CI CT ST
Splenius/chuck lean, %	2.03	2.28	2.60	2.39	2.22	.14	CI CT
Splenius ratio[d]	.35	.38	.42	.37	.37	.02	

[a] Implant treatments: C = control (non-implanted); S = Synovex-S on d 1; R = Revalor on d 1; ST = Synovex-S + TBA on d 1; STT = Synovex-S + TBA on d 1 and TBA reimplanted on d 58.

[b] Contrast effects:
CI (P<.05), ci (P<.10) = Control versus all implants;
CT (P<.05), ct (P<.10) = Control versus treatments with TBA;
ST (P<.05), st (P<.10) = Synovex-S versus treatments with TBA.

[c] Splenius weight is the dissected weight of the crest muscle.

[d] Splenius muscle weight divided by semitendinosus muscle weight.

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APPENDIX

CALCULATED CARCASS AND BOXED BEEF VALUE DIFFERENCES BETWEEN IMPLANTED AND CONTROL STEERS

FIGURE 1. ABSOLUTE BOXED BEEF VALUE DIFFERENCES OF IMPLANTED STEERS COMPARED TO CONTROLS

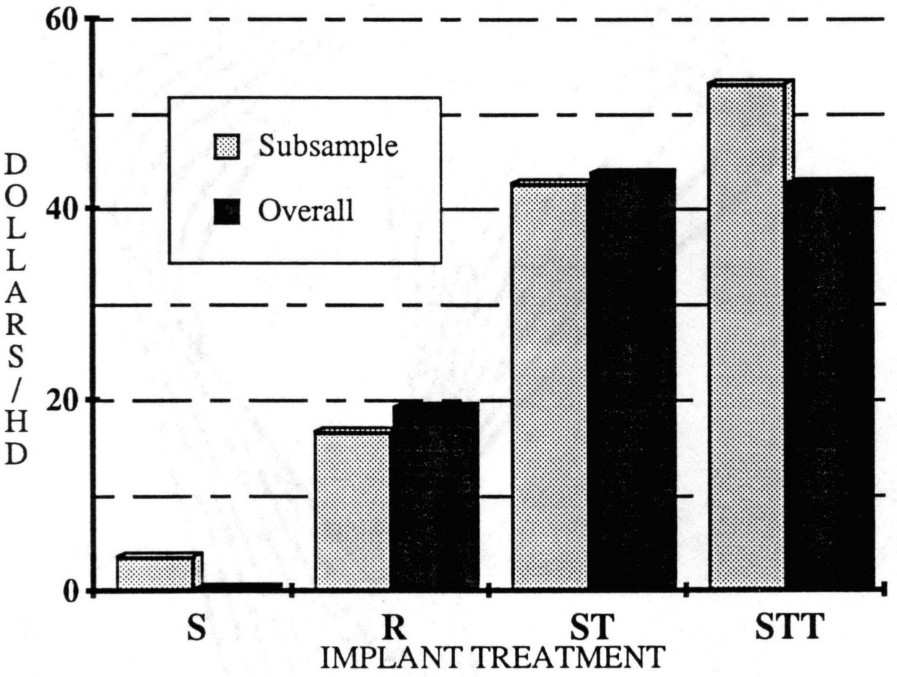


FIGURE 2. BOXED BEEF CUTOUT VALUE DIFFERENCES OF IMPLANTED STEERS COMPARED TO CONTROLS

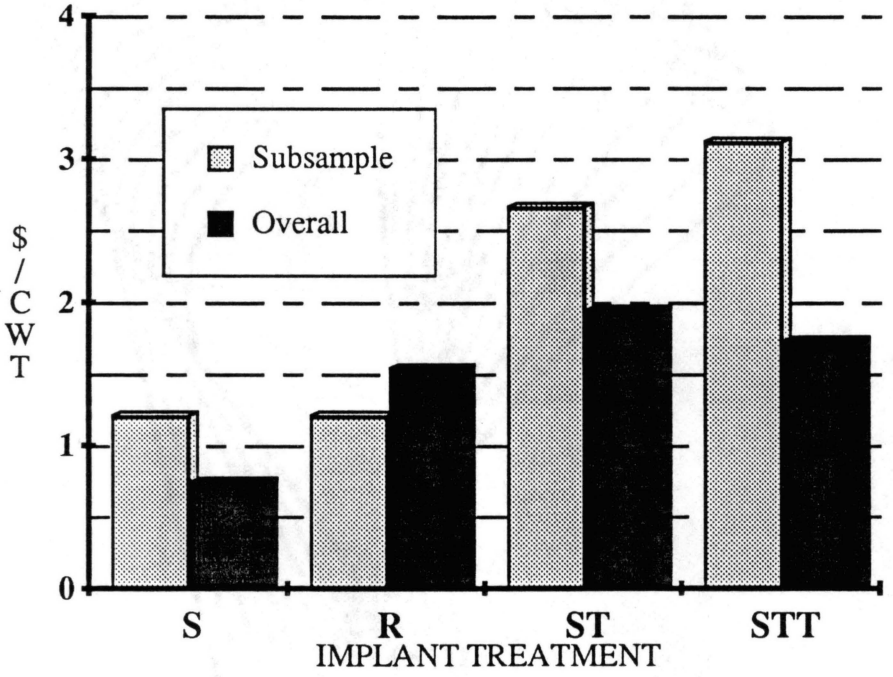


FIGURE 3. BOXED BEEF ADJUSTED LIVE VALUE DIFFERENCES OF IMPLANTED STEERS COMPARED TO CONTROLS

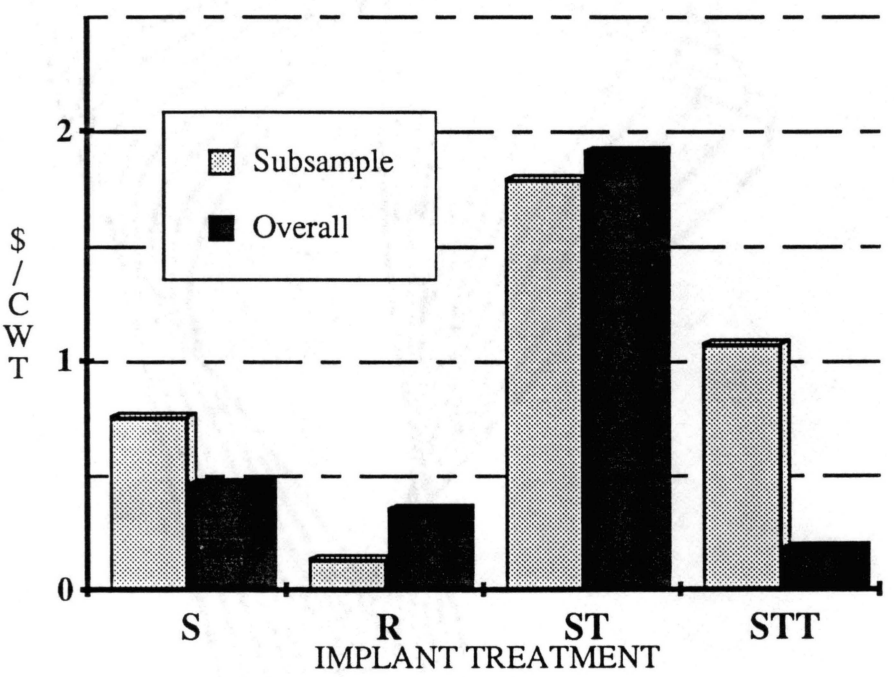


FIGURE 4. ABSOLUTE CARCASS BEEF VALUE DIFFERENCES OF IMPLANTED STEERS COMPARED TO CONTROLS

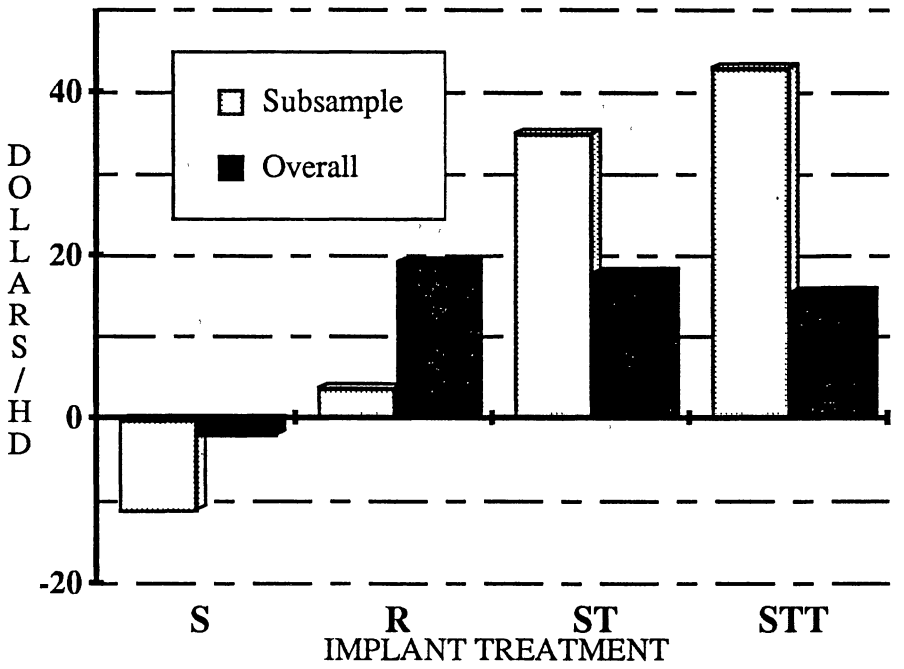


FIGURE 5. WHOLE CARCASS VALUE DIFFERENCES OF IMPLANTED STEERS COMPARED TO CONTROLS

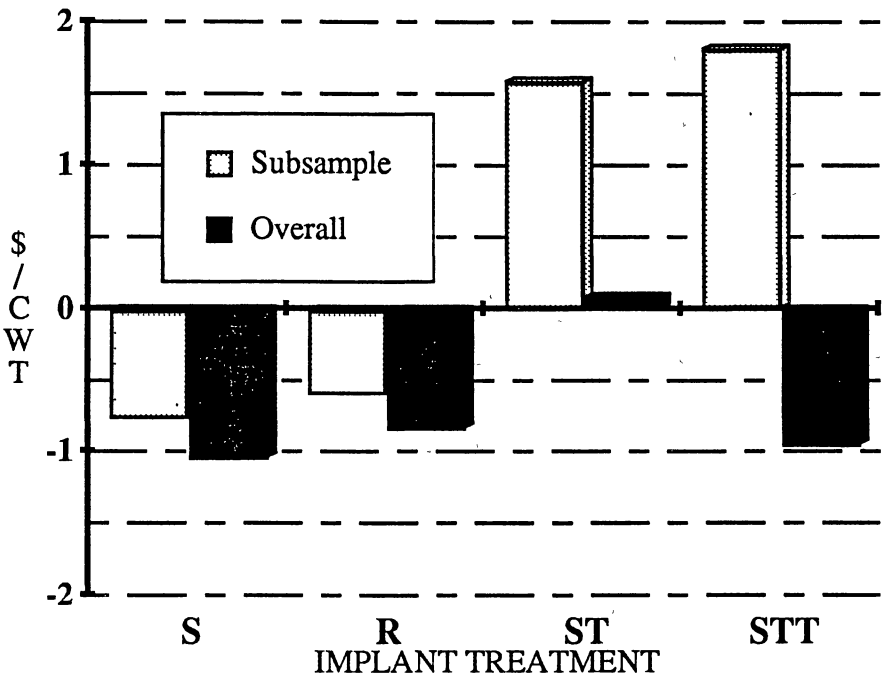
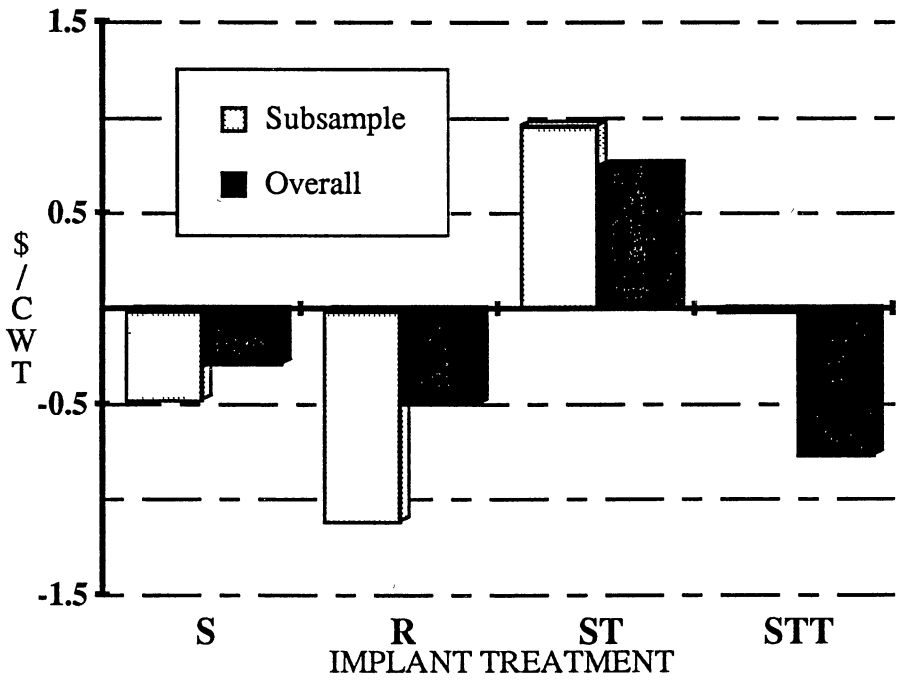


FIGURE 6. CARCASS ADJUSTED LIVE VALUE DIFFERENCES OF IMPLANTED STEERS COMPARED TO CONTROLS



VITA

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