ADMINISTRATION OF GROWTH-PROMOTING IMPLANTS AND DAYS ON FEED AFFECTED ALLOMETRIC GROWTH COEFFICIENTS, FABRICATION YIELDS, AND ECONOMIC RETURNS OF SERIALLY HARVESTED BEEF STEERS

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ABSTRACT

The objective of the first part of this study was to quantify differences in fabricated primals, subprimals, and carcass components of implanted and non-implanted steers. Steers (n = 80; initial BW 271 ± 99 kg) were paired and randomized to harvest date (d 0, 42, 84, 126, 168, 210, 252, 294, 336, 378). Individuals were randomized to treatment of CON (negative control) or REV (Revalor-XS; Merck Animal Health; Madison, NJ on d 0 and 190). One side of each animal was fabricated after a 48 h chill into primals, denuded subprimals, lean trim, trimmed fat, and bone; weights were recorded individually. Data were analyzed via mixed models. Implants increased cold side weights (CSW) 7.7%, bone yield 4.9%, and red meat yield 8.5% ($P < 0.03$), with no differences in fat yield ($P = 0.78$). Brisket and foreshank primals were increased 6.9% and 7.2%, respectively ($P \leq 0.02$) from implanted cattle. Chuck primals from REV steers were 8.4% heavier, with similar trends in the arm roast, flat iron, petite tender, chuck eye roll, and mock tender ($P \leq 0.02$). Rib primals of REV steers were 5.2% heavier, and the ribeye roll and rib blade meat showed an increase ($P \leq 0.04$). Plate primals did not differ between treatments ($P = 0.13$). However the inside skirt, outside skirt, and outside skirt as % CSW were heavier ($P \leq 0.04$) from REV steers. Loin primals from REV steers were 7.0% larger, along with the striploin, tenderloin, top sirloin butt, top sirloin butt cap, and bottom sirloin tri tip subprimals ($P < 0.01$). The flank primal of REV steers was 8.6% heavier, bottom sirloin flap and flank steak were also heavier ($P \leq 0.04$), and the elephant ear tended to be heavier ($P = 0.08$). Round primals from REV steers were 6.3% heavier,

and the top round, eye of round, bottom round, and knuckle were all heavier ($P \leq 0.03$) than CON. Length of feeding period notably affected weights for all primals with exception of the chuck, loin, and several components of the sirloin. Fat as % CSW increased at 0.043% per day, whereas bone and red meat yield decreased at -0.013% and -0.023% per day, respectively. These data indicate implanted steers are more likely to have heavier side weights, higher bone yield, and increased red meat yields. Additionally, heavier primals and subprimals were observed in implanted steers.

The objective of the second section of this study was to quantify allometric growth coefficients of non-carcass and carcass components of implanted or non-implanted Charolais × Angus steers in relation to empty body weight (EBW). Steers (n = 80; initial BW 271 ± 99 kg) were paired, randomized to harvest date (d 0-42-84-126-168-210-252-294-336-378), and individuals within pairs were randomized to CON (negative control) or REV (Revalor-XS on d 0 and 190) treatments. Weights (g) of non-carcass and carcass components were log transformed and consolidated to arithmetic means by treatment and harvest date. Growth coefficients were calculated using the allometric equation $Y=bX^a$, which when log transformed is represented as $Y=b+aX$ where Y= log(non-carcass or carcass component), X= log(EBW), a= log(slope), and b= log(intercept); the empty body grows at a rate of 1. Treatment outcomes were compared via independent t-test. Tendencies for faster growth of REV steers were detected in non-carcass components between treatments in the kidney ($P = 0.06$) and lungs/trachea ($P = 0.09$). Non-carcass components with lowest growth coefficients included small intestine (0.02), large intestine (0.12), and brain and spinal cord (0.13). However, kidney-pelvic-heart fat (2.01) accumulated at more than 2 times the rate of the empty body, whereas cod fat (1.42) and GIT fat (1.61) grew faster than the empty body. Growth coefficients were greater ($P < 0.01$) for REV in two carcass components (chuck eye roll, eye of round), whereas CON was greater ($P < 0.01$) in one component (flank steak). Although not different ($P > 0.62$), growth coefficients of carcass primals were numerically greater for REV steers with exception of the rib. All primals except the round (0.81) and foreshank (0.87) exhibited growth coefficients greater than the empty body (flank, 1.47; plate, 1.45; brisket, 1.18; rib, 1.18; loin, 1.04; and chuck, 1.03). Conversely, pectoral meat (0.19), bottom sirloin flap (0.56), heel meat (0.59), sirloin tip (0.66), and mock tender (0.69) subprimals all exhibited growth coefficients notably less than the empty body. Although not different, total lean was deposited more quickly in REV steers (0.95 vs 0.88; $P = 0.45$), whereas total fat (2.17 vs 1.98; $P = 0.35$) and total bone (0.92 vs 0.75; $P = 0.29$) were faster growing for CON steers. These data indicate total body fat exhibited the greatest growth coefficients compared to empty body. Whereas, there were minimal differences in growth coefficients of steers in regards to treatment.

The objective of the third section of this study was to compare the profitability of finished steers produced and processed in either a non-hormone treated (NHTC) or traditional implant program and marketed at various end points. Steers (n=80; Charolais×Angus) were paired by genetic group, estimated finished body weight, frame score, and d to target BW. Pairs were randomized to harvest date (d 0-42-84-126-168-210-252-294-336-378) and individuals within pairs were randomized to CON (negative control) or REV (Revalor-XS on d 0, 190). Live, carcass, subprimal, non-carcass drop, and overhead prices were consolidated from USDA Mandatory Price Reports and industry contacts. Data were analyzed via mixed models. Initial cost varied ($P < 0.01$)

between treatments as CON steers demanded premiums for NHTC and source verification. Feed costs were similar, and total production costs tended to be greater for CON (P = 0.09). Cattle marketed live or in the beef were of greater (P < 0.01) value for REV, as no premium was offered for NHTC steers. Quality grade adjustments tended to discount REV more heavily (P = 0.06), yield discounts tended to be greater for CON (P = 0.10), and weight based grid adjustments were unaffected by treatment (P = 0.53). Adjusted carcass value favored CON steers (P < 0.01) due to the NHTC premium. When sold on a live, in the beef, or grid basis, neither treatment yielded positive return. All variables with exception of initial cattle cost were different across DOF (P < 0.01). Non-carcass drop values were greater (P = 0.03) for REV. Boxed beef values were greater (P < 0.01) for CON. Processor net returns were calculated by difference in revenue (boxed beef plus non-carcass drop) and expense (overhead [-$190/carcass] plus procurement of the grid purchased carcass). Net return for processors was similar between treatments (P = 0.65). These data indicate implanted steers returned greater revenue when marketed on a live or in the beef basis, whereas NHTC steers returned more value when marketed on a grid basis, although neither treatment was profitable. Additionally, there was no difference between treatments in regards to the profitability of beef processors.

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CHAPTER 1

INTRODUCTION

Increasing carcass weight is a key value driver when making management decisions for animals marketed on a value-based grid. Growth of carcass components with increased days on feed (DOF) leads to increased carcass weights (May et al., 2017, Schmitz et al., 2018). Lean and bone as a percentage of carcass weight often decreases, whereas fat percentage is directly correlated to longer DOF (May et al., 1992; Hermesmeyer et al., 2000; Rathmann et al., 2009; May et al., 2017). USDA Yield Grade (YG) is an indicator of cutability and amount of lean yield expected from a carcass. Increased DOF has been correlated with increased YG (Greene et al., 1989). However, administration of growth promoting implants has been shown to decrease YG while increasing saleable red meat yield (RMY; Foutz et al., 1997; Kellermeier et al., 2009). Primal weights have been proven to increase overall in the presence of implants, and most noticeably in the round (Forrest, 1978; Foutz et al., 1997) and chuck (Neill et al., 2009; Kellermeier et al., 2009).

Hormone-free marketed beef products have gained popularity with consumers, and beef processors have begun to feel the pressure for more of these products. A recent survey reported 57% of consumers are concerned about hormones in their meat products (Food Market Institute, 2018). Steers raised without implants have a higher degree of USDA Quality Grade (**QG**) than conventionally raised animals, but conventional animals have lower YG and heavier HCW (Woodard and Fernández, 1999). The percentage of cattle not receiving an implant at the feedlot has increased 3 - 6 percentage points (depending on feeder cattle entrance weights) from 1999 to 2011 (NAHMS, 2013).

We hypothesize HCW will increase linearly with DOF, and animals administered implants will have increased HCW, primal, and subprimal weights compared to non-implanted animals at similar time points. The purpose of this study was to examine fabricated yields of implanted or non-implanted steers at varying DOF.

Allometric growth, a term first developed by Huxley and Teissier (1936), refers to growth of a part in relation to the whole, represented by $y=bx^a$. Where y represents the scale of difference or piece, x is whole body size, a is a constant differential growth ratio, and b is a slope for the ratio of y:x (White and Gould, 1965; Gayon, 2000). Differences in relative growth have been speculated to be affected by nutrition, ratio of muscle to bone, genetics, and amount of fat distribution (Butterfield, 1966). Berg and Butterfield (1966) reported that early maturing muscle groups, such as those most distal from the trunk, exhibited fastest growth rates, whereas late maturing groups, such as those most proximal to the trunk, grew slowest. Similarly, Hammond and Appleton (1932) quantified growth gradients in lambs, and reported limbs most proximal to the trunk grew at the slowest rates, whereas those distal to the trunk grew fastest from birth to weaning in comparison to the cannon bone. Growth rates of lean, fat, and bone are not similar and even within component are not the same (Berg and Butterfield, 1968). Implants have been shown to increase deposition of lean tissue and decrease fat deposition in the carcass (Bruns et al., 2005) and increase overall live weight (Samber et al., 1996).

We hypothesize an increase in carcass lean components and a decrease in fat accretion in animals administered growth-promoting implants. The objective of this study was to evaluate the allometric effects of growth-promoting implants on carcass and non-carcass components.

More than 92% of all cattle in a feedlot setting receive at least one implant (NAHMS, 2013), subsequently enhancing animal value during finishing (Duckett and Andrae, 2001; Wileman et al., 2009) and reducing production costs by 6.5% (Lawrence and Ibarburu, 2007). This reduction in costs is a direct result of a 20% improvement in average daily gain (ADG) and enhanced gain to feed (G:F) efficiency by 14% (Duckett and Andre, 2001) to 27% (Wileman et al., 2009). Conversely, Non-Hormone Treated Cattle (NHTC) only make up about 0.5% of cattle harvested in the 2011 National Beef Quality Audit (Moore et al., 2012), and are traditionally marketed to the European Union or to niche channels domestically (AMS, 2019). Presence of non-hormone treated cattle in the marketplace at a feeder level increased 18.6 percentage points from 2010 to 2018, whereas percentage of implanted lots remained constant (McCabe et al., 2019). These non-implanted animals need to receive a premium at some level to offset the insufficiencies in less effective feed conversion and lowered average daily gain compared to their implanted counterparts.

Profit at harvest is of foremost importance to producers. Producers who market cattle on a live basis are solely driven by finished body weight, whereas those who market cattle on a grid are concerned with premiums and discounts in addition to HCW. Implants have been proven to increase finished body weight 6 to 8% compared to non-implanted steers (Guiroy et al., 2002). Increases in HCW by 3 to 4% have also been observed when steers were administered implants (Bruns et al., 2005). Cattle in a non-hormone treated program are traditionally lighter, but are eligible for premiums when marketed as feeder calves (from 1.02 to 4.04%, McCabe et al., 2019), stocker calves, and live cattle sold on a grid basis (on average $20/cwt, USDA, 2020).

We hypothesize increased weight gain from implant administration will outweigh premiums received for non-hormone treated cattle. The objective of this study was to evaluate the profitability of various marketing endpoints for cattle marketed via conventional or non-hormone treated cattle programs.

In regards to all sections of this project, our overarching objective was to quantify the effects of implant status and feeding duration on the fabricated yields, allometric growth, and economic analysis of serially harvested beef steers.

CHAPTER 2

REVIEW OF LITERATURE

2.1. Allometric growth

Allometric growth, a term first developed by Huxley and Teissier (1936), refers to growth of a part in relation to the whole. At its origin, allometry was specifically used to describe growth of a body part compared to a whole body. Early observations of male fiddler crabs led to questions regarding growth of its disproportionately large claw, followed by research on body and claw size (Huxley, 1924). Collection of body and claw lengths over various stages of development generated data that exhibited a curvilinear relationship, which when log-transformed, indicated claw growth occurred at a rate faster than whole body, resulting in noted enlargement. This research laid a foundation for interest in allometric growth. Both Huxley and Teissier formed the equation for allometric growth, $y=bx^a$, in 1936. Where **y** represents the scale of difference or piece, **x** is whole body size, **a** is a constant differential growth ratio, and **b** is a slope for the ratio of y:x (White and Gould, 1965; Gayon, 2000).

2.1.1. Allometry and stage of development

In decades following original publication of agreed upon verbiage for "allometry", questions concerning relationships between allometry and ontogenesis, defined as the development of an organism from fertilization as an egg to adulthood, arose. Work regarding theories of early development of individuals, ontogenesis, and modern synthesis became popular in the 1940's and comparison to allometry occurred heavily from 1950 to 1970.

Butterfield (1966) assessed factors that cause change in relative growth of beef cattle. Firstly, nutrition is suspected to play a primary role in post-natal development of these animals. Other notable points of influence include muscle-weight distribution, muscle to bone ratio, and amount or distribution of fat. Based on previous works by Butterfield and Berg (1966) cattle tend to grow similarly in muscular distribution which is relative to individual muscle use demanded in the body. Muscle to bone ratios suggest this value will increase as muscle plus bone weight increases. Lastly, deposition of fat location is largely influenced by genetics, whereas quantity of fat deposition is dependent upon levels of nutrition and days on feed. While genetics play a large role in the developmental structure of animals, individual species growth is the primary focus of allometric growth curves and equations.

Work on molting stages of pea-crabs by Atkins (1926) showed growth rate of carapace length occurred slowest proximal to the abdomen and gradually increased in the most distal areas, at a rate of 1.30 to 1.73, respectively compared to the whole body. This paper served as one of the first indicators of appendages growing more rapidly than body and posed questions regarding gradients and uniformity of growth throughout an animals' life.

Ideas of growth occurring more rapidly in distal limbs of livestock were discovered by Hammond and Appleton (1932). Evaluation of growth gradients of sheep extremities, with cannon bone as a constant, lambs showed an increased growth rate of the limb-girdle, humerus, tibio-fibula, tarsals/carpals, and metatarsals/metacarpals from birth to 5 months of age. The author also noted hind limbs may be more developed at birth and grow quickly in order for the lamb to follow the mother, a result of evolution. Lamb size at birth was speculated to be affected by litter size, as animals born a triplet exhibited the smallest bone ratios and the largest animal was single-born. During adolescent and adult stages of growth, growth occurred at a fast rate distally, decreasing proximate to the trunk.

Butterfield and Berg (1966) further classified stages of growth to muscle groups as early, average, late, or very late maturing. Similar to Hammond and Appleton (1932), early maturing muscle groups were those of thoracic and distal pelvic limbs, whereas the latest maturing muscle groups were in regions of neck to thoracic limb, with average and late maturing groups falling in-between. Results indicated lowest growth rates generally occur in early maturing muscles, and highest growth rates occur in late or very late maturing muscle groups. These results are expected, as early maturing muscle groups would exhibit highest levels of growth soon after birth and plateau quickly. Whereas, late and very late maturing muscle groups would reach peak growth near the end of maturity.

Varying growth rates depending on stage of maturity was evaluated by Huxley (1927). Male fiddler crabs experience rapid growth of their chelae, only once they reach puberty, suggesting this change is related to hormonal changes. Each region of claw grows in a fashion of rapid growth in areas distal to the body, and slow growth in areas proximal to the body. These data suggest stage of development can effect growth rate, which was further supported Huxley (1950). The allometric equation may not accurately estimate growth in every circumstance; stages of development may be a potential source of error in growth rate fluctuations around puberty (Huxley, 1950).

2.1.2. Evaluation of the allometric equation

White and Gould (1965) substituted superscript **a** in the allometric equation with **k**, which both represent the ratio between y:x, also referred to as a constant differential growth rate. This line of thought assumed **a** is constant throughout measured periods of growth. In comparison, values regarding **b** are not well defined, and researchers have argued its importance, Huxley (1950) stated, "the constant **b**… has no biological or general significance". Challenges in understanding **b** arise when units are applied, as **y**, **x**, and **a** are each numbers represented by given units, values of **b** will change significantly based on standard units. Some researchers believe **b** is an indicator of differences in populations within species of animals, or an effect of programmed size prior to birth (ontogenesis). Changes in **b** that occur because of evolution without respective changes in **a**, led White and Gould (1965) to conclude **b** has retained significance within the allometric growth equation. Representation of **b** in this sense is best agreed upon as a scaling factor.

Yields are of foremost importance in beef cattle, as they represent the saleable carcass and non-carcass components. This concept sparked Kidwell et al. (1951) to evaluate the allometric growth equation as a means to predict body conformation. The authors reported logarithmic transformation of the allometric equation resulted in a -1.0 correlation coefficient of variables **a** and **b**, suggesting they may represent identical values. Coefficients **a** and **K** of the allometric equation were not heritable, at values not differing from zero.

2.1.2.1. Coefficient b as a representation of population variances

Early on, Thompson (1961) visually compared two horse skeletons at a museum, and noted differences in cannon bone size. One horse was an accomplished cart pulling Clydesdale with short thick cannon bones, and the other a successful racing horse with long slender cannon bones. Using this information, Thompson suggested a standard value for bone growth based on animal size or even species may not be sufficient when accounting for other evolutionary factors within species such as animal type and purpose. While no standard body part was suggested, the author suggested adopting a standard to compare the body growth for each population of animals.

2.1.2.2. Coefficient b as a representation of evolutionary factors

Smith (1983) evaluated mandibular size of 253 adult female primates encompassing 32 different species, and multiple taxonomic classifications. As a whole, primates tended to experience increased mandible size with growth in overall body size, but observations within groups of animals consuming diets of leaves or those of nuts, fruits, and berries did not exhibit similar tendencies, suggesting the evolutionary effects of diet are accounted for by the coefficient b.

Davis (1962) studied muscle growth in lions and domestic house cats, as both are closely related organisms with similar diets and behaviors, but with noticable differences in size. Data indicated lions have smaller skeleton weight in relation to body size compared to a domestic cat, as well as a greater ratio of muscle to bone. This is discussed as a result of necessity, because cats require a greater degree of agility, and lions require great speed in short bursts.

Measurements of rabbit growth patterns for determination of growth pattern standardization were evaluated by Castle (1914). To avoid bias from animals with faster or longer growth curves than others, researchers concluded measurements of correlation should be compared to the head as a general standard for body growth. Since then, the whole body remains the most common standard of comparison.

2.1.2.3. Coefficient b as a representation of scaling

An incredibly insightful paper by Gould (1971) explored all avenues for defining and clarifying the value of **b**, which was thought to represent size-independent differences among regressions. Gould concluded **b** represents a scaling factor, as it modifies outcomes of the equation when size is changed, and range of shape remains unaltered. This theory indicates regression equations for any given data set will be similar whereas **b** represents the differences in size. This is different from initial concepts as it is dependent on the size of comparable animals with constant values of **a**.

Red deer antler weight in allometric relationships has also been used for scaling of live weight ranges in evaluation of **b** as a scaling factor (Ball et al., 1994). Similarities in growth rates among populations, with age differences confirm theories of antler maturity as a late trait in relation to live weight. Supporting this theory, antler growth ratios increased in a linear fashion with age as two year olds produced antlers smaller than those of any other age group, whereas four-year-old deer developed the largest antlers in relation to body size. This information suggested there may be genetic influences to certain organ systems with greater biological importance, whereas **b** is used to homogenize data to a similar scale.

An Australian study calculated allometric coefficients in fattening steers from 300 to 600 kg for 15 major wholesale cuts of beef (Priyanto et al., 2009). Muscle growth occurred slightly faster than body only in the chuck, brisket, rib, and plate, whereas all other regions had coefficients less than one. Fat overall was most heavily deposited with **b** coefficients twice as great as side growth, where subcutaneous fat accumulated at almost three times as fast as the side weight, and bone coefficients were all less than side growth. These data indicate muscle growth happens most rapidly in forequarter, whereas subcutaneous fat is deposited primarily in dorsal regions, and bone growth remains relatively low in relation to side growth.

2.1.3. Allometry of carcass components

Relationships in compositional growth are effected by a number of factors, including age, sex, breed, nutrition, and many more. Berg and Butterfield (1968) evaluated growth patterns of carcass components based on consolidation of information from a number of published works, and reported muscle, fat, and bone each have varying growth rates in relation to allometric growth. Muscles grow fastest after birth and continue increasing at a decreasing rate for the remainder of growth. During late maturity, a phase will be reached where fat deposition occurs at a rate greater than muscle growth. Bone deposition occurs at consistently low rates in relation to other components throughout all periods of growth. Additionally, growth rates do not occur evenly throughout the body, and can be inclined towards greater fat deposition in ventral regions. Breed differences between beef and dairy type animals indicate that beef animals deposit fat at earlier stages of muscle development. In regards to sex, heifers tend to finish at lower weights and have higher fat percentages in carcass components than steers. In market-ready animals, weight plays an important role in carcass composition, as overall weight increases we often observe percentage of muscle and bone decrease, concomitant with fat increase.

Live and carcass outcomes of heifers were evaluated at varying end points on *ad libitum* or maintenance level diets (Yambayamba, 1996). At 50 and 92 d, fat as a portion of side weight was greater for *ad libitum* cattle, whereas bone in relation to side weight was greater in cattle fed at maintenance. After restricted cattle were offered *ad libitum* diets, side fat remained less than *ad libitum* animals until 134 days post-restriction. Liver weight was smaller in nutrient restricted cattle, but quickly became heavier as these cattle began receiving *ad libitum* diets. This research suggests growth of carcass components can greatly be affected by dietary intake levels.

Growth curves of dairy heifers fed at adequate or restricted intakes to quantify body component growth was evaluated by Eckles and Swett (1918). Wither height was used as a reference point for skeletal growth, and changes in body weight was used to define total body growth. In heifers being fed at maintenance, growth occurred at 73 to 88% of normal, whereas heifers fed a ration above maintenance experienced growth rates 118 to 130% above average between six months to two years of age. Skeletal growth proved to be more consistent with both treatments growing from 93 to 103% of normal. These data indicated nutrient restriction can greatly influence growth of the whole body, however skeletal growth is maintained during early pre-pubertal periods, regardless of dietary influences.

Live and carcass performance of beef-type steers fed for 140 days on one of three treatments; non-implanted control, early implant on day 0, or delayed implant on day 57

(Revalor-S) was evaluated by Bruns et al. (2005). Average daily gain did not differ, but gain to feed ratios were greatest in implanted treatments. Hot carcass weight, dressing percentage, and longissimus area were all greater for implanted treatments. USDA yield grade also decreased in the presence of implants. Conversely, marbling score was highest and maturity scores were youngest in non-implanted steers. Overall, these data suggested implants positively influenced live performance, hot carcass weight, and red meat yield, but negatively influenced marbling scores and skeletal maturity.

Live performance and carcass quality were evaluated on beef-type steers in one of seven treatments including a negative control and several variations of timing, frequency, and type of implant (Samber et al., 1996). Implanted steers had heavier live weights, higher gain to feed ratios, and increased average daily gain compared to non-implanted animals. Carcass weights and dressing percentage were not different among treatments. Marbling score was highest in non-implanted animals and those receiving implants delayed at least 30 d. These findings indicated early implant use can improve live performance variables, but may decrease carcass quality.

2.1.4. Allometry of viscera

Harvest of gerbils between weaning and adult ages was conducted by Wilber and Gilchrist (1965) for quantification of organ growth in relation to overall body weight. Researchers reported thyroid, kidneys, adrenals, brain, pituitary, lung, and eyes all exhibited increasing growth ratios when log transformed, whereas heart, spleen, and body length showed an increasing linear relationship with body weight when untransformed. Allometric relationships exist within organs, where some grow faster and others slower than the empty body weight. Understanding these realtionships can assist in defining more accurate and reliable prediction equations for segmented body growth.

Changes in viscera weights and empty body compositions in four different implant groups of genetically identical steers was evaluated by Hutcheson et al. (1997). Treatments administered included non-implanted control, estrogenic implant, androgenic implant, or androgen-estrogen combination. In steers administered estrogen containing implants, gastrointestinal tract full weights of GIT, spleen, liver, pluck, and kidney as a percent of EBW tended to be lightest. Liver and spleen weights had a tendency to be heaviest in steers administered combination implants. Hides tended to be heaviest in steers supplied estrogen. Empty body protein was highest for androgen-estrogen combination, whereas non-implanted steers were lightest by weight, treatments did not differ in terms of empty body weight percentage or overall marbling scores. Consequently, estimated rate of protein deposition was highest in androgen-estrogen combination and lowest in non-implanted steers. These data suggested the use of combination implants have a tendency to increase protein accretion, liver, spleen, and hide weights, all while decreasing total organ mass compared to single or no hormone implant.

2.2. Fabrication yields

2.2.1. Fabrication styles and history

International beef cutting styles are variable given the region, history, culture, and demand of a given subprimal cut. Language barriers and derivations are believed to play a larger role in breakdown of beef carcasses than anatomical preferences of a region. Swatland (2012) illustrated this concept in regards to the anatomical location of the sirloin primal. The author noted the word sirloin originates from surlonge, which means on or above the loin, and in Britain translates to anterior of the loin (Figure 2.1.). This is also highly variable depending on whether a carcass was fabricated on a flat surface or hung from a rail. Similarly, this author noted the location of an undistinguishable cut on a diagram of a beef carcass from 1876. It was reported in the shoulder of the animal, and was labelled as the *spaud*; further discussion by Swatland uncovered the transformation of this word. It passed to *épaule* in French, *spatulae* in Latin, and finally *espadilla* in Spanish - all of which translate to scapula or shoulder blade.

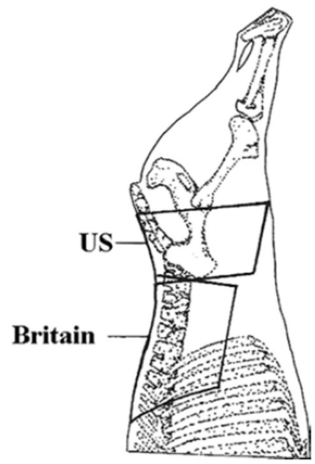

Figure 2.1. Anatomical location of the sirloin in the United States and Britain. Extracted from Swatland (2012)

During World War II and the rationing of meat to consumers, the U.S. Office of Price Administration was involved in developing a standard cutting style and quality grading system for all commercial beef carcasses to ensure similar prices and marketing. Carcass grading systems were created by the government to increase catergorization, and in turn marketability, within a class of similar products. Grading then occurred on all beef carcasses according to government guidelines, and a standard method of fabrication was adopted. While a variety of fabrication methods existed, the Chicago cutting style was modified and adopted as the standard, likely because of its proximity and immersion in the beef industry. Bull et al. (1944) provided a figure to show gridlines used in standard beef fabrication of primals (Figure 2.2.), and to a lesser degree of standardization the fabrication of retail cuts (Figure 2.3.).

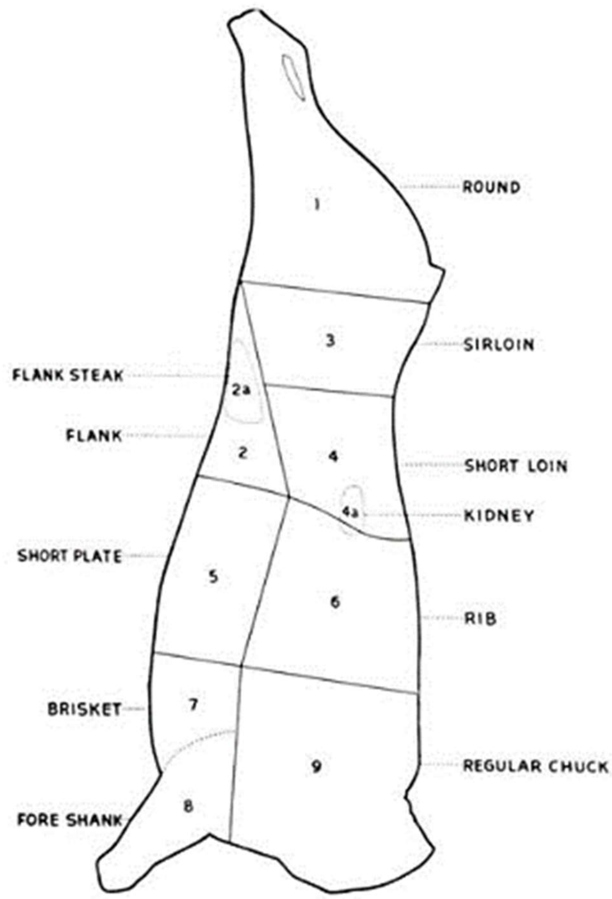

Figure 2.2. Beef primal fabrication gridlines according to the Office of Price Administration. Extracted from Bull et al. (1944)

Location, supply, demand, personal preferences, and many other factors play a role in determining cutting styles utilized in any given area of the United States. For example, Romans et al. (2001) acknowledged the round may be cut into three relatively different, but recognized styles, each with their own benefits and drawbacks. The round can be removed from the carcass via a Chicago style, New York style, or Diamond style cut. Each of the cutting styles are depicted in Figure 2.4.

Today, the most common style is the Chicago style round, which involves cutting the round primal "at the junction of the last sacral vertebra and the first caudal vertebra and passes through a point anterior to the prominence of the aitch bone" (Romans et al., 2001). This cutting style accounts for 22.5% of the total carcass weight and leaves the head of the femur exposed. However, this method cuts through the sirloin tip (quadriceps), leaving a portion of the sirloin attached to the round and a portion attached to the loin.

The New York style is an intermediate between the Chicago and Diamond style fabrication methods. This cut simply involves removing the sirloin tip prior to the separation of the round from the carcass, which can then be removed using Chicago style methods (Romans et al., 2001). The sirloin tip would be included in the weight of the round, resulting in a round accounting for 25% of the total carcass weight.

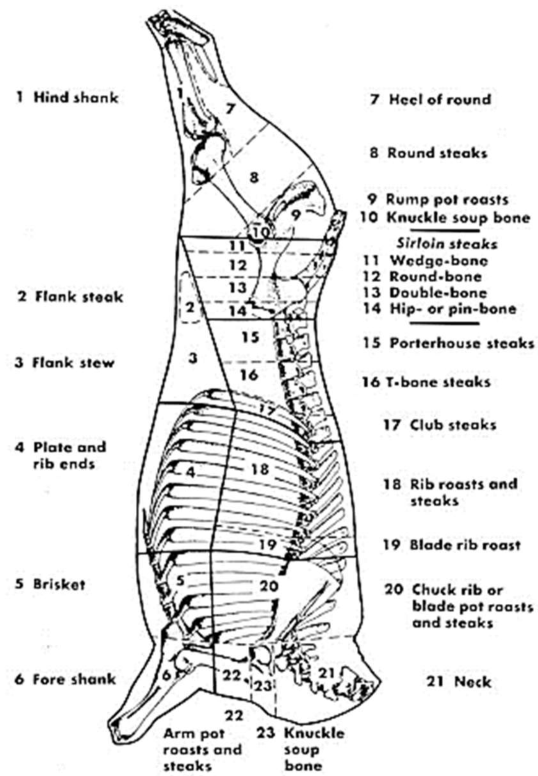

Figure 2.3. Beef retail cuts fabrication guidelines. Extracted from Bull et al. (1944).

The Diamond style round is similar to the Chicago method and recognized as the most useful cut, but also as the most challenging to apply correctly. The initial cut is similar to the Chicago style method where the femur head is exposed, however the cut would not continue through the flank primal. Instead, the cut would continue along the angle of the aitch bone, resulting in a sirloin tip entirely attached to the round (Romans et

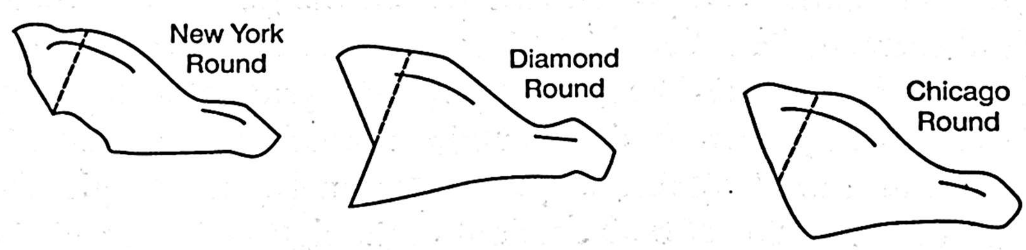

Figure 2.4. Depictions of New York, Diamond, and Chicago style rounds. Extracted from Romans et al. (2001)

al., 2001). Similar to the New York style round, this method would account for 25% of the carcass weight, but leaves the sirloin tip attached to the round.

2.2.2. Yield of cold side weight and carcass components

Carcass side weights are increased simultaneous with increasing days on feed (May et al., 2017; Schmitz et al., 2018). Red meat yield is positively correlated to days on feed in regards to overall pounds however lean often decreases as a percentage of cold side weight (Rathmann et al., 2009; May et al., 2017). Bone is similar to red meat yield, in which weight is increased numerically and percentage cold side weight is decreased in relation to increased days on feed (May et al., 2017). Conversely, total fat yield of the carcass is often directly related to days on feed in terms of weight and percentage of cold side weight (May et al., 1992; Rathmann et al., 2009; May et al., 2017).

Schmitz et al. (2018) reported steers allowed to consume an *ad libitum* diet increased the cold side weight, red meat, and fat mass over steers fed a diet formulated to meet maintenance requirements. On a percentage of cold side weight basis, fat yield was also increased on an *ad libitum* diet. Overall, subprimals were larger when steers were fed longer. Rathmann et al. (2009) reported similar results, in which the majority of measured carcass composition variables followed a linear or quadratic response in relation to days on feed. Similarly, the salable red meat yield percentage was decreased as a percentage of cold side weight.

USDA Yield Grade (YG) is continually noted to increase linearly as DOF increases (Greene et al., 1989; May et al. 1992; Rathmann et al., 2009). However, the presence of a combination implant has been shown to decrease USDA YG and 12th rib fat thickness compared to non-implanted animals, while still maintaining the ability to increase ribeye area (Foutz et al., 1997; Kellermeier et al., 2009). An increase in carcass protein accretion has been noted in animals administered combination estradiol-trenbolone acetate implants (Gerken et al., 1995; Johnson et al., 1996; Baxa et al., 2010). These factors are key in an implant's ability to increase hot carcass weight and dressed carcass yield (Baxa, 2008). Dressed carcass yield exhibited a linearly increasing trend with increased days on feed (May et al., 1992). Additionally, percentage of KPH in the carcass has been continually decreased in implanted animals (Johnson et al., 1996; Hermesmeyer et al., 2000; Baxa, 2008; Baxa et al., 2010), compared to non-implanted animals with increasing days on feed (May et al., 1992; Rathmann et al., 2009).

Use of hormonal implants has been documented to increase the HCW and RMY of animals receiving these implants. Platter et al. (2003) reported that administering a Revalor implant upon feedlot entry and feedlot re-implant resulted in steers with carcasses more than 25 kg heavier than non-implanted steers. Additionally, double implanted animals had larger LMA area and decreased YG compared to non-implanted steers; however, the non-implanted steers had a higher percentage of carcasses grade USDA Choice and Prime. Similar results for carcass quality were seen in animals given Revalor at d 30 and d 130 in a feedlot (Samber et al., 1996), with higher USDA QG for non-implanted steers. Animals fed to 1.4 cm of subcutaneous fat had increased quality grades over those fed to 1.0 cm of subcutaneous fat (Hermesmeyer et al., 2000), likely a result of increased days on feed.

Natural methods of raising cattle have been rising in popularity over the last several decades, as consumers begin to push for "natural" products. This push from consumers has given way to premiums from beef processors for non-hormone treated animals and in response, a new era of research has been explored. Conventional and organic systems of cattle production from calf-hood to feedlot were studied by Woodard and Fernández (1999). Organically raised steers had increased marbling scores and quality grades, but also required increased days on feed to reach similar end points. Conventionally raised steers had heavier hot carcass weights, larger REA, and lower YG than the organic animals. May et al. (1992) reported animals not administered implants accrued marbling in a quadratic trend relative to increasing days on feed coupled with an increasing linear trend for REA. Revalor-S implantation also resulted in decreased marbling score compared to non-implanted steers, also noting increased REA in implanted animals (Hermesmeyer, et al., 2000).

2.2.3. Subprimal yields

Individual steroid and combination steroidal implants are well documented to increase carcass weights, but the primals that are specifically affected by implants have not been confidently identified. Few researchers have quantified primal or subprimal weight differences in animals with or without implants.

In regards to primal weight differences, Foutz et al. (1997) described an overall increase in primal weights of animals administered a Revalor implant. Neill et al. (2009) reported animals administered Revalor-200 had a heavier chuck, round, and brisket of fed cows. Revalor-S was determined to increase weights in chuck, loin, and round primals as well (Kellermeier et al., 2009). Forrest (1978) also reported heavier rump, hind shank, and hindquarter weights, as well as an increase in overall carcass lean and a decrease in carcass fat deposition in relation to unimplanted steers. When compared to bulls, implanted steers exhibited similarities in growth of the forequarter and neck, but deposited a greater amount of fat overall and increased subcutaneous to intermuscular fat ratio (Wood et al., 1986).

The shoulder clod, chuck roll, chuck mock tender, tenderloin, bottom sirloin flap, tri-tip, and flank steak, and all of the round subprimals were larger in implanted animals (Kellermeier et al., 2009). In addition, implanted animals had more lean trimmings and less fat trim. The administration of a second steroidal combination implant again resulted in even heavier subprimal categories (Al-Maamari et al., 1996). More specifically, the gooseneck round and chuck roll were larger in animals implanted once or twice as compare to those receiving no implant (Al-Maamari et al., 1996). Foutz et al. (1997) also noted a heavier boneless chuck, striploin, and greater total percentage of lean from Revalor treated animals. Top butt weight was also increased in implanted steers regardless of breed type (Perry et al., 1991). These data suggest heavier subprimal weights are likely to exist in the chuck, loin, and round of implanted steers.

2.3. Economic analysis

2.3.1. Summary of program requirements and demand

In accordance with the USDA Agricultural Marketing Service (AMS), cattle endorsed as non-hormone treated must meet the three following requirements (FSIS, 2007):

1. Cattle must be clearly identified and raised in an approved operation with proper documentation including certification agreeing the cattle adhere to the requirements for verification of products with a program exported to the European Union (EU; discussed in more detail below).

2. Slaughter establishments must segregate animals and carcasses of animals in this program to ensure animals are not comingled.
3. Export certification occurs after tissue sampling and approval from the Food Safety Inspection Service (FSIS).

Within the requirement to verify export to the EU, guidelines state animals must not be administered hormonal growth promotants at any time in their life, animals must be clearly identified, and information regarding place of purchase/transfer, diet ingredients and their sources, and any bills of lading, letters of guarantees, or shipping manifests must be easily traceable. Aside from these requirements, approved producers will also be randomly audited every fiscal year and at greater frequency if non-compliance occurs (AMS, 2019).

Elam and Preston (2004) suggest that increased usage of growth promoting implants in the last fifty years has led to an increase in rate of gain by 15 to 20% and improvement in feed efficiency by 8 to 12%. Using implants has therefore led to lower cost of gains and increased saleable weight, resulting in added benefits to producers. Improvements in carcass characteristics have increased benefits for packers and consumers. Authors also noted the ease of implant programs to be tailored to a producer's goals, whether it be days on feed, final carcass weight, USDA quality grade, or yield grade. Moreover, Duckett and Andrae (2001) evaluated implant administration programs based on timing and goals of individual producers. They reported an increase in value of the animal based on improvements in average daily gain and increase in live weight. Cattle implanted in the feedlot increased value by $51.34, whereas cattle implanted in all phases increased value by $92.86/animal compared to cattle not receiving an implant.

The use of implants in beef cattle production has been pivotal in improving quantity of beef produced.

In order to be profitable when marketing niche products, producers must be able to sell their products in a market where consumers are willing to pay premiums for these specialty products. Thilmany et al. (2003) surveyed consumers in various areas of Colorado to determine regional influences on a consumer's desire to pay more for a "natural" product, in this case defined as the animal being raised without hormones or antibiotics and never confined to small or crowded pens. Authors reported consumers are becoming more conscious of the content in animal feeds, how animals are being medicated, and how these animals are raised. Participants in this study were most likely to purchase natural beef if they classified themselves as owning a freezer, having kids, or being a hunter. Authors also noted availability of these natural products, grocers, and ranchers were heavy influencers of buying decisions. In areas with greater presence of natural grocers, consumers bought more natural products. Consumers were also willing to pay a greater premium for natural ground beef than natural beef steaks, which the author suggests was due to the relative premium of a ground product.

2.3.2. Production system economics

Use of pharmaceutical technologies has essentially become standard in the beef industry. Administering cattle a growth promoting implant occurs at arrival of feedlot in cattle weighing < 700 lbs and ≥ 700 lbs at 92.3% and 94.3%, respectively. Of those feedlots, cattle weighing < 700 lbs and ≥ 700 lbs were administered two or more implants to 79.9% or 29.8% of cattle (NAHMS, 2013). Lawrence and Ibarburu (2007) evaluated costs associated with eliminating commonly used technologies, such as dewormers, implants, antibiotics, and ionophores. They reported these technologies reduced costs $126.09/hd. Implants alone provided the greatest cost savings at $68/hd, a 6.5% reduction in overall costs. This reduction in costs was directly associated with cost of production through improving ADG and Gain:Feed, and did not account for any premiums given in cattle not receiving these technologies.

2.3.3. Grid-based economics

While marketing cattle in a grid-based marketing system may introduce the possibility for differentiated prices for superior quality and yield grades, and marketing programs, producers are ultimately paid for carcass weight. Feuz (2002) performed a simulated economic analysis on the effects of harvesting cattle two weeks ahead of or behind their typical end-point to evaluate economic changes. Allowing cattle an additional two weeks on feed increased USDA QG. However, the discounts associated with increased yield grade and heavy carcasses in addition to added days on feed often negated this premium. Conversely, cattle harvested two weeks before their typical end-point had lower yield grades and lower feed costs, but at a detriment to quality grade and carcass weight. Ultimately, this author suggested the ideal harvest endpoint is one that accounts for all variables without neglecting pounds, as producers are paid premiums and discounted on a per cwt basis.

Similarly, Retallick et al. (2013) reported HCW to have a strong regression relationship (R^2 = 0.93) to carcass value per steer, reinforcing weight as a primary influencer of revenue. Profit was positively influenced by average daily gain (R^2 = 0.63) and negatively influenced by cost of gain (R^2 = -0.53). Residual body weight gain was inversely correlated with feed conversion ratio (R^2 = -0.71), and cost of gain was strongly correlated to feed conversion ratio ($R^2 = 0.84$). These data again indicated profit is indicated by average daily gain, cost is influenced by cost of feed per pound of gain, and overall revenue is strongly correlated to hot carcass weight.

McEvers et al. (2018) reported the effects of zilpaterol hydrochloride on calf-fed Holsteins serially harvested at eleven endpoints. Discounts were greater for heavier carcass weights and higher yield grades as animals were on feed longer, regardless of ZH or CON treatment. Conversely, increased days on feed resulted in higher quality grades and increased premiums. Although no differences were detected between treatments on a per cwt basis, the dressed yield differences between the two treatments would have likely influenced the overall value of the entire carcass.

Weight being a primary influencer of income, variability in weight of cattle on natural versus commercial programs could be the difference in profit or loss for many producers. Although the average slaughter steer weighed 1427 lbs in 2019 (USDA, 2020), NASS (2019) data from 2009 reported the average commercial cattle finished weight for 2009 was 1294 lbs, without separating these two groups of cattle. Springer et al. (2009) discovered, by survey, the average final weight goal for those producing natural cattle is 1200 lbs. Moreover, this researcher reported 78% of respondents identified as natural producers required cattle to be source verified, likely indicating these cattle would be sold into an export market. Acceptance for paying a premium on naturally produced cattle were common in 84% of respondents, and feedyards were willing to pay an average premium of $4.76 above base price for feeder cattle. Information from this survey is indicative of natural cattle production, but it did not differentiate specific programs such as never-ever, non-hormone treated, organic, etc.

In a meta-analysis of modern technologies, steers administered hormonal growth promotants increased average daily gain 0.25 kg/d and increased dry matter intake by 0.53 kg/d compared to negative controls (Wileman et al., 2009). Implanted steers also improved gain to feed ratios from unimplanted controls (0.17 vs 0.15), which ultimately led to the lowest costs of production. Hormonal growth promotants decreased cost of production $77 compared to non-implanted animals, and $349 compared to organically fed steers. These data suggest using implants will increase live performance and decrease overall cost of production, but does not account for premiums given by non-implanted or organic animal marketing programs. However, the exact price for non-implanted animal premiums in order for these animals to achieve similar performance as the implanted animals was not reported in this study.

Conventional or organic production management strategies were evaluated (Thompson et al., 2008) for their effects on calf growth and carcass traits. Treatment weights were similar when animals entered the finishing phase, and conventionally managed animals were heavier and had more efficient average daily gain in the feedlot. Hot carcass weights were greater in conventionally raised animals, but marbling scores were slightly higher in natural animals, with all other measured carcass traits being similar. Authors mentioned that while an economic analysis was not performed, this is an area where more information is needed to provide breakeven cost information and potential profits.

Organic cattle are defined as those living in areas accommodating for their natural behaviors, fed a diet composed of 100% organic feed and forage, and not administered antibiotics or growth promoting hormones (Code of Federal Regulations, 2020). Non-hormone treated cattle (NHTC) on the other hand have two main requirements, the animal must be traceable back to its farm of origin and it must never receive a hormonal growth promotant at any time during its life (AMS, 2019). Natural products are defined as a product that is minimally processed and contains no artificial ingredients, this term is not related to the treatment of the live animal, but rather the processing required for the final product (FSIS, 2015). It is important to differentiate the requirements for each of these terms in regards to legal definitions for marketing. There is minimal research available for non-hormone treated cattle and their economic value in comparison to implanted cattle. However, there is a slightly larger reserve of data available comparing the overall returns of organically raised cattle to those receiving implants. Additionally, a conventional program is legally unregulated, the producer has the ability to decide the inclusion or use of antibiotics, ionophores, implants, β-agonists, etc. Presenting a clear definition of each of these terms will help consumers understand the background involved in the treatment of the live animal and subsequent food products.

Maxwell et al. (2015) evaluated differences in a program with an implant (conventional), or the same program without an implant (natural). They reported cattle on a conventional program gained 0.4 kg/d faster and increased G:F ratio by 0.032 kg/kg over naturally raised steers. Converse to similar studies, carcass grading characteristics were similar among treatments, however natural cattle did decrease 12^{th} rib fat thickness by 0.10 cm. Administration of a growth promoting implant resulted in a 38 kg increase in HCW and a 8 cm^2 larger REA. These data indicate the use of implants can result in more efficient animals and greater returns on heavier carcasses.

Fernández and Woodward (1999) evaluated feedlot production costs associated with raising calves in conventional or organic systems at the preconditioning and feedlot levels. Similar to Thompson et al. (2008), they concluded steers were most feed efficient and had the best rates of gain when managed under a conventional system. Additionally, conventional management resulted in about 28 fewer days on feed to reach targeted endpoints than those under organic management. Costs of feed per kg of gain was $0.99 and $1.50 for conventional and organic steers, respectively, resulting in a 39% higher cost to feed organic animals during the finishing phase.

Maxwell et al. (2014) also evaluated natural and conventionally raised steers from growing into finishing phases. Conventionally raised steers received an implant at 250 kg and were 19 kg heavier than their non-implanted counterparts upon entering the finishing phase. Conventional steers received another implant upon entry into the feedlot at 385 kg where they finished 50 kg heavier than the natural steers due to increased DMI (0.76 kg/d), improved ADG (0.42 kg/d), and more efficient G:F ratios (0.032 kg/kg). Hot carcass weight was 62 kg heavier in conventional steers, dressing percentage was 1.58% higher, REA was 16.94 cm^2 larger, and USDA YG was 0.45 lower than natural steers. Conversely, natural steers exhibited 79 point higher marbling scores and 30% more natural cattle graded premium choice.

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CHAPTER 3

FABRICATION YIELDS OF SERIALLY HARVESTED IMPLANTED OR NON-IMPLANTED STEERS

3.1. Abstract

The objective of this study was to quantify differences in fabricated primals, subprimals, and carcass components of implanted and non-implanted steers. Steers (n = 80; initial BW 271 ± 99 kg) were paired and randomized to harvest date (d 0, 42, 84, 126, 168, 210, 252, 294, 336, 378). Individuals were randomized to treatment of CON (negative control) or REV (Revalor-XS on d 0 and 190). One side of each animal was fabricated after a 48 h chill into primals, denuded subprimals, lean trim, trimmed fat, and bone; weights were recorded individually. Data were analyzed via mixed models. Implants increased cold side weights (CSW) 7.7%, bone yield 4.9%, and red meat yield 8.5% ($P < 0.03$), with no differences in fat yield ($P = 0.78$). Brisket and foreshank primals were increased 6.9% and 7.2%, respectively ($P \leq 0.02$) from implanted cattle. Chuck primals from REV steers were 8.4% heavier, with similar trends in the shoulder clod, flat iron, petite tender, chuck eye roll, and mock tender ($P \leq 0.02$). Rib primals of REV steers were 5.2% heavier, and the ribeye roll and rib blade meat showed an increase in weight ($P \leq 0.04$). Plate primals did not differ between treatments ($P = 0.13$), however the inside skirt, outside skirt, and outside skirt as % CSW were heavier ($P \leq 0.04$) from REV steers. Loin primals from REV steers were 7.0% larger, along with the striploin,

tenderloin, top sirloin butt, top sirloin butt cap, and bottom sirloin tri tip subprimals ($P <$ 0.01). The flank primal of REV steers was 8.6% heavier, bottom sirloin flap and flank steak were also heavier ($P \leq 0.04$), and the elephant ear tended to be heavier ($P = 0.08$). Round primals from REV steers were 6.3% heavier, and the top round, eye of round, bottom round, and knuckle were all heavier ($P \leq 0.03$) than CON. Length of feeding period notably affected weights for all primals with exception of the chuck, loin, and several components of the sirloin. Fat as % CSW increased at 0.043% per day, whereas bone and red meat yield decreased at -0.013% and -0.023% per day, respectively. These data indicate implanted steers are more likely to have heavier side weights, higher bone yield, and increased red meat yields. Additionally, heavier primals and subprimals were observed in implanted steers.

3.2. Introduction

Increasing carcass weight is a key value driver when making management decisions for animals marketed on a value-based grid. Growth of carcass components with increased days on feed (DOF) leads to increased carcass weights (May et al., 2017, Schmitz et al., 2018). Lean and bone as a percentage of carcass weight often decreases, whereas fat percentage is directly correlated to longer DOF (May et al., 1992; Hermesmeyer et al., 2000; Rathmann et al., 2009; May et al., 2017). USDA Yield Grade (YG) is an indicator of cutability and amount of lean yield expected from a carcass. Increased DOF has been correlated with increased YG (Greene et al., 1989). However, administration of growth promoting implants has been shown to decrease YG while increasing saleable red meat yield (RMY; Foutz et al., 1997; Kellermeier et al., 2009). Primal weights have been proven to increase overall in the presence of implants, and most noticeably in the round (Forrest, 1978; Foutz et al., 1997) and chuck (Neill et al., 2009; Kellermeier et al., 2009).

Hormone-free marketed beef products have gained popularity with consumers, and beef processors have begun to feel the pressure for more of these products. A recent survey reported 57% of consumers were concerned about hormones in their meat products (Food Market Institute, 2018). Steers raised without implants have a higher degree of USDA Quality Grade (**QG**) than conventionally raised animals, but conventional animals have lower YG and heavier HCW (Woodard and Fernández, 1999). The percentage of cattle not receiving an implant at the feedlot has increased 3 - 6 percentage points (depending on feeder cattle entrance weights) from 1999 to 2011 (NAHMS, 2013).

We hypothesize HCW will increase linearly with DOF, and animals administered implants will have increased HCW, primal, and subprimal weights compared to non-implanted animals at similar time points. The purpose of this study was to examine fabricated yields of implanted or non-implanted steers at varying DOF.

3.3. Materials and methods

3.3.1. Live animal and carcass fabrication

Live animal care and use, live growth performance, feeding behavior, harvest characteristics, and carcass grading were detailed previously by Kirkpatrick (2020) and Pillmore (2020). After harvest and a 48-h chill, the right side of each carcass was fabricated at the West Texas A&M University Meat Lab (USDA Est. 7124) according to Institutional Meat Purchase Specification (**IMPS**) guidelines. Personnel fabricated the same primal at every time point, to avoid any changes in technique. Bruises were removed at harvest. Kidney, pelvic, and heart fat (**KPH**) was removed and weighed during harvest (Pillmore, 2020).

Each chilled carcass was weighed hanging on the rail and the trolley weight was subtracted to represent the cold side weight (**CSW**). Primals [Foreshank (IMPS #117), Brisket (IMPS #118), Chuck, Square-Cut (IMPS #113), Rib, Primal (IMPS #103), Plate, Short Plate (IMPS #121), Loin, Full Loin, Trimmed (IMPS #172), flank, and Round, Primal (IMPS #158)] were separated from the carcass, weighed to the nearest 0.01 kg, and recorded. All subprimals were completely denuded of external fat, weighed to the nearest 0.01 kg, and again recorded. For each side, the following subprimals were obtained: Brisket, Deckle-Off Boneless (IMPS #120); Chuck, Shoulder (Clod); Arm Roast (IMPS #114E); Chuck, Shoulder (Clod); Top Blade (IMPS #114D); Chuck, Shoulder, Tender (IM) (IMPS #114F); Chuck, Chuck Roll (IMPS #116A); Chuck, Chuck Tender (IMPS #116B); Chuck, Square-Cut, Pectoral Meat (IM) (IMPS #115D); Rib, Ribeye Roll, Lip-On (IMPS #112A); Rib, Back Ribs (IMPS #124); Rib. Short Ribs, Trimmed (IMPS #123B); Rib, Blade Meat (IMPS #109B); Plate, Outside Skirt (IM) (IMPS #121C); Plate, Inside Skirt (IM) (IMPS #121D); Loin, Strip Loin, Boneless (IMPS #180); Loin, Tenderloin, Full, Side Muscle Off, Defatted (IMPS #190); Loin, Top Sirloin Butt, Center-Cut, Cap Off (IM), Boneless (IMPS #184B); Loin, Top Sirloin Butt, Cap (IMPS #184D); Loin, Bottom Sirloin Butt, Ball Tip, Boneless (IMPS #185B); Loin, Bottom Sirloin Butt, Tri-tip, Defatted, Boneless (IMPS #185D); Flank, Flank Steak (IMPS #193); Loin, Bottom Sirloin Butt, Flap, Boneless (IM) (IMPS #185A); Round, Top (Inside), Untrimmed (IMPS #168); Round, Sirloin Tip (Knuckle), Peeled (IMPS #167A); Round, Outside Round (Flat) (IMPS #171B); Round, Eye of Round (IM) (IMPS

#171C); and Round, Outside Round, Heel (IMPS #171F). Additionally, the hanging tender (diaphragm) and elephant ear (cutaneous trunci) were weighed. Inside skirt was collected in the flank and plate primals, summed, and reported with the plate primal. After weighing, individual subprimals along with lean trimmings (target 80/20) were combined and weighed to the nearest 0.1 kg to calculate red meat yield (**RMY**). Bones were closely trimmed to remove any excess lean and weighed together to represent bone yield for each side. Trimmable fat from each subprimal was combined to represent fat yield of the side. Additionally, each primal, subprimal, and component were expressed as a percentage of the CSW (**% CSW**).

3.3.2. Statistical analysis

A balanced incomplete block design was used with a 2 × 10 factorial treatment arrangement. The MIXED procedure of SAS was used to analyze the fixed effects of implant TRT, days on feed (**DOF**), and TRT × DOF interaction with d 0 body weight (**BW**) used as a covariate, and pair as a random effect. Mean estimates were calculated using LSMEANS. Differences were identified at $\alpha \leq 0.05$ and tendencies were recognized at $0.05 < \alpha \leq 0.10$. Linear and quadratic trends for DOF were analyzed using CONTRAST statements, and significance was acknowledged at $P \leq 0.05$. Prediction equations were calculated using the REG procedure, where all eight animals harvested on d 0 were analyzed as CON.

3.4. Results and discussion

3.4.1. Carcass component yields

Cold side weight and overall weight of carcass components are presented in Table 3.1. Bone yield was confounded by TRT × DOF interaction ($P < 0.01$), likely as a result of experimental error (Appendix G). Red meat yield and fat yield were not affected ($P \geq$ 0.49) by TRT × DOF interaction. Implanted steers had 12.5 kg heavier ($P < 0.01$) CSW than their non-implanted counterparts. Implanted animals are commonly observed to have 8.9 to 11.4% heavier carcasses than non-implanted animals (Hermesmeyer et al., 2000; Platter et al., 2003; Parr et al., 2011). Red meat yield was 8.2 kg heavier ($P < 0.01$) for REV steers. No difference was observed ($P = 0.78$) in fat yield. Similar studies have shown longissimus area is increased in implanted steers by 6.5 to 9.2% (Roeber et al., 2000; Parr et al., 2011), total percentage of lean is increased (Foutz et al., 1997), and yield grade is unaffected by implant usage (Bartle et al., 1992; Johnson et al., 1996). Bone yield was increased ($P = 0.03$) 1.5 kg for REV compared to CON steers. All components exhibited an increasing trend ($P < 0.01$) in weight correlated to increasing DOF. Increasing days on feed has consistently been shown to increase weight of individual carcass components (Greene, et al., 1989; May et al., 2017; Schmitz et al., 2018). All carcass components were evaluated as a percentage of CSW to provide a timeless measurement of percentage change. No differences were detected ($P \geq 0.18$) in red meat, bone, or fat yield as % CSW. Similar research has shown the percentage of each carcass component remains constant regardless of implant status (Rathmann et al., 2009).

Changes in overall primal weights are presented in Figure 3.1. The greatest changes in primal weights occurred in the flank and the chuck, increasing 8.6 and 8.4%, respectively compared to the non-implanted steers. Conversely, the plate and rib exhibited the least change, only increasing 4.3 and 5.2% from the non-implanted steers (Figure 3.1). In regards to individual components, lean was increased anywhere from

7.2% in the round to 11.5% in the plate in the implanted steers (Appendix A). Fat decreased deposition in the plate and rib of implanted steers at 5.4 and 2.2%, respectively, whereas fat deposition was increased 7.0% in the round and virtually unaffected in the brisket and chuck at 0.1% and 0.6%, respectively compared to the non-implanted steers (Appendix B). Bone weights were decreased 3.1% in the rib, and increased in all other primals, most notably at 13.6% in the brisket of implanted steers compared to the non-implanted steers (Appendix C).

Fat yield increased quadratically at approximately 0.043% of CSW per day, whereas red meat yield and bone decreased quadratically at approximately 0.023% and 0.012% of CSW per day, respectively (Table 3.3). All carcass components and leanness as a % CSW were effected ($P < 0.01$) by DOF. Muscling was unaffected ($P = 0.90$) by DOF. Individual primal weights expressed as a % CSW were affected by DOF in all primals ($P < 0.01$) with exception of the chuck and loin ($P \geq 0.17$) The brisket primal weight exhibited an increasing linear relationship, whereas foreshank weight exhibited decreasing linear relationships to increased DOF. The rib, plate, and flank weights as a % CSW all exhibited increasing quadratic relationships, whereas the round exhibited a decreasing quadratic relationship to increased DOF. These results suggest while the weight of individual components may be increased when steers are implanted, their percentage of the carcass remains similar to non-implanted steers.

Changes in overall primal weights for varying DOF in regards to each primal are presented in Figure 3.2. Individual primals were increased anywhere from 112 to 393% in the foreshank and flank, respectively compared to d 0 (Figure 3.2). Lean was increased anywhere from 64% in the foreshank to 278% in the plate compared to d 0 (Appendix D).

Fat was deposited most rapidly in regards to carcass components across DOF. Fat weights were not collected in the foreshank, but increased the least at 433% in the brisket and 527% in the round; whereas the greatest changes in fat deposition occurred at 1511% in the plate and 1534% in the rib (Appendix E). Bone weights were increased anywhere from 70% in the brisket, upwards to 313% in the plate (Appendix F).

Proportion of leanness, or the ratio of total muscling to total fat, was numerically 2.49% higher in REV steers than non-implanted steers, but did not differ ($P = 0.76$). Leanness was quadratically associated with DOF decreasing at approximately -0.016% of CSW per day ($P < 0.01$). Muscling was confounded by TRT × DOF interactions ($P < 0.01$), likely as a result of experimental error (Figure 3.10). Proportion of muscling, or the ratio of total muscle to total bone, was not different between treatments ($P = 0.27$).

3.4.2. Carcass primal yields

All carcass primals were converted to their respective % CSW for treatment comparisons. All variables were unaffected by TRT × DOF interaction ($P \geq 0.21$), with exception of the brisket ($P = 0.06$). Although implants were able to increase weight of individual primals, the percentage of each primal remained consistent regardless of implant status, and there was no difference between treatments of primals as % CSW ($P \geq 0.13$). All primals with exception of the chuck and loin ($P \geq 0.17$) exhibited a relationship in % CSW with DOF ($P < 0.01$). Prediction equations for carcass components and primals exhibiting a relationship to DOF are presented in Table 3.3. The brisket, rib, plate, and flank all increased ($P < 0.01$) with increasing DOF, whereas the foreshank and round decreased ($P < 0.01$) as % CSW in relation to increasing DOF. Leanness, fat yield, plate and flank primals as % CSW were the best fitted to the predictors of the data (Adj. $R^2 > 0.64$). Leanness also presented the highest RMSE value at 1.57, likely due to a large variation in leanness at the beginning of the study (Appendix J).

In regards to primals, the brisket weight ($P = 0.06$) was the only variable confounded by TRT × DOF interaction ($P \geq 0.21$; Table 3.2), likely a result of experimental error (Figure 3.11). All primals were numerically heavier for REV than CON. The foreshank (+0.44 kg; +7.2%), brisket (+0.62 kg; +6.9%), chuck (+3.68 kg; +8.4%), rib (+0.83 kg; +5.2%), loin (+1.71 kg; +7.0%), flank (+0.94 kg; +8.6%), and round (+2.45 kg; +6.3%) primals were heavier ($P \leq 0.04$) from REV steers than non-implanted steers (Figure 3.1). Although not different ($P = 0.13$), the plate was 0.64 kg (4.3%) heavier. The flank, loin, and plate exhibited the greatest growth rate of all primals at 0.009%, 0.007%, and 0.004% of the CSW per day, whereas the round grew slowest at -0.017% of CSW per day. Studies have consistently shown implanted animals have greater weights of individual primals than non-implanted animals (Forrest et al., 1987; Foutz et al., 1997), especially in the chuck and round (Kellermeier et al., 2009; Neill et al., 2009). All variables experienced a relationship in weight correlated to increasing DOF ($P < 0.01$). Quadratic trends were observed in the absolute weights of the foreshank, brisket, chuck, rib, loin, flank, and round primals ($P \leq 0.02$), and the weights as % CSW in the rib, plate, flank, and round ($P \leq 0.04$). Linear relationships were observed in the % CSW of the brisket and foreshank ($P < 0.01$). No relationship to DOF ($P \geq 0.17$) was observed in % CSW of the chuck or loin primals. Increasing DOF has been proven to increase primal weights (Rathmann et al., 2009; Schmitz et al., 2018), similarly to the present study. The flank, loin, and plate increased fastest at 0.009%, 0.007%, and 0.004%

of CSW per day, respectively; whereas, the round decreased the fastest at -0.017% of CSW per day. Brisket primals increased at 0.002% of CSW per day. Rib did not change from the % CSW. Chuck and foreshank decreased at -0.001% and -0.002% of CSW per day.

3.4.3. Carcass subprimal yields

Minimal research has been reported to show changes in subprimal weights over time or in regards to implant treatment. Carcass yields for subprimal within the brisket are presented in Table 3.4, chuck in Table 3.5, rib in Table 3.6, plate in Table 3.7, loin in Table 3.8, and flank in Table 3.9, and round in Table 3.10.

Absolute brisket weight was confounded by TRT × DOF interactions ($P = 0.05$; Table 3.4) potentially as a result of experimental error (Appendix K). The brisket was heavier for REV steers ($P < 0.01$), but did not differ as a % of CSW ($P = 0.74$). Increasing DOF resulted in increased brisket weight in a quadratic trend ($P < 0.01$).

Within the chuck (Table 3.5), there were no subprimal TRT × DOF interactions ($P \geq 0.12$). The arm roast, flat iron, petite tender, chuck eye roll, and mock tender were all heavier for REV steers ($P \geq 0.02$). Although not different ($P = 0.21$), pectoral meat was numerically heavier for REV steers. Kellermeier et al (2009) reported heavier shoulder clod, clod tender, chuck eye roll, mock tender, and pectoral meat in implanted steers than non-implanted steers, similar to the findings in the current study. Differences observed in this study and others in regards to pectoral meat could occur due to lack of consistency in defining the location of pectoral meat. All chuck subprimals were similar as % CSW ($P \geq 0.30$). Quadratic trends ($P \leq 0.02$) with days on feed were observed for the arm roast, flat iron, petite tender, chuck eye roll, mock tender, and pectoral meat on an absolute weight basis as well as pectoral meat and flat iron on % CSW basis ($P <$ 0.01). Linear trends were observed in the arm roast, petite tender, chuck eye roll, and mock tender as % CSW ($P \leq 0.02$). Rathmann et al (2009) reported chuck subprimals as % CSW and noted many linear trends, similar to those observed in the present study.

In the rib primal (Table 3.6), absolute weight of back ribs were effected by TRT × DOF interactions ($P = 0.05$) as a result of experimental error (Appendix L). Ribeye roll and rib blade meat were heavier for REV steers ($P \leq 0.02$). Although numerically heavier in REV, no differences were observed in the back ribs or short ribs ($P \geq 0.13$). Conversely, Kellermeier et al. (2009) reported no differences among subprimals in the rib of implanted animals. However, if the implant administered in the Kellermeier et al. (2009) study was a higher dosage and similar to the implant administered in the present study, we would expect similar results would have been observed. All rib subprimals were similar between treatments on a % CSW basis ($P \geq 0.20$). Quadratic trends were observed for the ribeye roll, rib blade meat, and short rib weights ($P \leq 0.02$), and as % CSW in back ribs, and short ribs ($P \leq 0.02$). Back rib weights and rib blade meat as % CSW were linearly associated to DOF ($P < 0.01$).

Plate subprimals (Table 3.7) were unaffected by TRT × DOF interactions ($P \geq$ 0.32). Outside and inside skirts were heavier in REV steers ($P < 0.01$). Outside skirt was heavier as % CSW for REV ($P = 0.04$), and inside skirt was similar ($P = 0.51$). Quadratic trends to DOF were observed in the inside skirt weight ($P < 0.01$). Linear associations to DOF were observed in the outside skirt weight and the outside and inside skirt as % CSW ($P < 0.01$).

Within the loin (Table 3.8), all subprimals were unaffected by TRT × DOF interactions ($P > 0.17$). Weight of the striploin, tenderloin, top sirloin butt, top sirloin butt cap, and bottom sirloin tri tip were all heavier for REV ($P \leq 0.01$). No difference was noted in bottom sirloin ball tip or hanging tender weights between treatments ($P \geq 0.20$). Loin subprimals were similar on a % CSW basis ($P > 0.11$). Similar results were observed by Kellermeier et al. (2009) in which all loin subprimals except the bottom sirloin ball tip were heavier in implanted animals. The bottom sirloin ball tip is often created by cutting error when separating the loin and round; inconsistencies in exact cutting location could be the cause of the similar results between treatments observed in this study and others. Quadratic trends for DOF existed in striploin, tenderloin, top sirloin butt, top sirloin butt cap, and bottom sirloin tri tip weights ($P \leq 0.05$), as well as the tenderloin, top sirloin butt, top sirloin butt cap, and bottom sirloin ball tip as % CSW ($P \leq 0.02$). The bottom sirloin ball tip and hanging tender absolute weights, as well as the striploin, bottom sirloin tri tip, and hanging tender as % CSW were linearly associated with DOF ($P < 0.01$).

Flank subprimals (Table 3.9) were unaffected by TRT × DOF interactions ($P \geq 0.36$). Bottom sirloin flap and flank steak were heavier for REV steers ($P \leq 0.01$). Tendencies were also observed for heavier elephant ears ($P = 0.08$) in REV steers. Flank subprimals were also heavier for implanted steers in a similar study by Kellermeier et al (2009). Flank subprimals as % CSW were similar between treatments ($P \geq 0.28$). Increasing DOF effected the absolute weight of the bottom sirloin flap and elephant ear, as well as the flank steak and elephant ear as % CSW in a quadratic manner ($P \leq 0.03$).

Flank steak absolute weight increased with increasing DOF in a linear fashion ($P < 0.01$). Bottom sirloin flap as % CSW was unaffected by DOF ($P = 0.28$).

Round subprimals (Table 3.10) were unaffected by TRT × DOF interactions ($P \geq 0.21$). All round subprimals ($P \leq 0.03$) except heel meat ($P = 0.74$) were heavier for REV steers than CON steers. Kellermeier et al. (2009) also reported an increase in round subprimals in implanted animals. Round subprimals were all similar in % CSW ($P \geq 0.20$). All round subprimals in weight and % CSW were effected by DOF ($P < 0.01$). Quadratic trends were observed in absolute weight of the top round, eye of round, and sirloin tip ($P \leq 0.01$) and as a % CSW in all round subprimals ($P \leq 0.05$). Linear trends were observed in the absolute weight of the bottom round and heel meat ($P < 0.01$). Similar to results in Rathmann et al. (2009), the round subprimals as % CSW are observed to decrease with increased DOF.

3.5. Implications

These data indicate CSW as well as bone yield and red meat yield are heavier in implanted steers, whereas fat yield remained similar. All primals except the plate, and the majority of subprimals were heavier in implanted steers. However, when carcass components, primals, and subprimals were expressed as a percentage of CSW, few differences were observed between the treatments. All variable absolute weights and a majority of weights as % CSW were effected by increasing DOF. Quadratic trends were observed in a large portion of the variables in relation to increasing DOF. As a whole, implanted steers were heavier, but the proportion of each variable to the CSW was similar between non-implanted and implanted steers.

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Table 3.1. Effect of Revalor-XS[1] implant administration and days on feed (DOF) on cold side weights (CSW) and fabrication yields of Charolais × Angus steers

Item	Treatment[2]			Days on feed (DOF)												*P*-value				
	CON	REV	SEM	0	42	84	126	168	210	252	294	336	378	SEM	TRT× DOF	TRT	DOF	Linear	Quadratic
n	40	40		8	8	8	8	8	8	8	8	8	8						
CSW, kg	163.3	175.8	1.92	77.9	101.6	121.5	147.9	168.4	195.4	198.3	212.9	223.0	248.4	4.34	0.23	**<0.01**	**<0.01**	<0.01	**<0.01**
Fat yield, kg	34.5	35.0	1.14	6.5	11.9	17.2	29.2	32.6	38.7	40.8	58.0	54.0	58.6	2.72	0.78	0.78	**<0.01**	**<0.01**	0.11
% CSW	19.3	18.2	0.56	7.5	11.6	13.9	19.7	19.5	19.7	20.9	27.1	24.3	23.2	1.34	0.66	0.18	**<0.01**	<0.01	**<0.01**
Bone yield, kg	30.8	32.3	0.53	17.5	22.2	24.7	26.3	31.8	36.8	38.0	35.3	39.6	43.3	1.33	0.88	**0.03**	**<0.01**	<0.01	**0.01**
% CSW	19.1	19.1	0.30	22.1	21.9	20.4	17.9	18.8	18.9	19.3	16.7	17.8	17.5	0.89	**<0.01**	0.82	**<0.01**	**<0.01**	0.09
Red meat yield, kg	96.3	104.5	1.60	49.8	66.8	78.1	87.3	98.7	117.4	120.8	116.9	123.6	144.8	3.81	0.64	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	60.0	60.4	0.71	64.2	65.6	64.2	59.1	58.6	60.1	61.3	55.0	55.4	58.4	1.69	0.49	0.69	**<0.01**	**<0.01**	0.25
Leanness[3]	4.01	4.11	0.23	10.37	5.85	4.88	2.93	3.25	3.24	3.01	2.09	2.31	2.68	0.56	0.91	0.76	**<0.01**	<0.01	**<0.01**
Muscling[4]	3.16	3.22	0.06	3.13	3.02	3.15	3.36	3.12	3.19	3.18	3.32	3.13	3.34	0.17	**<0.01**	0.27	0.90	-	-

[1]Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control

[3]Leanness was calculated as the ratio of total muscle to total fat

[4]Muscling was calculated as the ratio of total muscle to total bone

Table 3.2. Effects of Revalor-XS[1] implant administration and days on feed (DOF) on primal yields of Charolais × Angus steers

Item	Treatment[2]			Days on feed (DOF)												P-value				
	CON	REV	SEM	0	42	84	126	168	210	252	294	336	378	SEM	TRT× DOF	TRT	DOF	Linear	Quadratic
n	40	40		8	8	8	8	8	8	8	8	8	8						
Foreshank, kg	6.13	6.57	0.12	3.60	3.23	5.08	5.86	6.66	7.36	7.56	8.07	8.41	7.64	0.28	0.21	**0.01**	**<0.01**	<0.01	**<0.01**
% CSW	3.84	3.84	0.07	4.78	3.21	4.20	3.98	3.95	3.78	3.80	3.80	3.77	3.13	0.18	0.25	1.00	**<0.01**	**<0.01**	0.69
Brisket, kg	9.05	9.67	0.18	3.89	5.13	6.78	7.45	8.80	10.86	11.73	12.93	12.73	13.31	0.41	**0.06**	**0.02**	**<0.01**	<0.01	**<0.01**
% CSW	5.47	5.40	0.09	4.91	5.04	5.58	5.00	5.22	5.54	5.91	6.06	5.71	5.38	0.20	0.60	0.56	**<0.01**	**<0.01**	0.07
Chuck, kg	43.56	47.24	0.65	20.89	27.90	32.29	40.73	45.89	51.97	52.29	55.40	59.09	67.58	1.54	0.33	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	26.75	26.92	0.18	26.85	27.35	26.60	27.61	27.25	26.56	26.36	26.04	26.57	27.16	0.41	0.90	0.51	0.17	-	-
Rib, kg	16.04	16.87	0.28	6.87	8.98	10.66	14.55	16.79	18.71	19.89	20.79	22.65	24.68	0.62	0.54	**0.04**	**<0.01**	<0.01	**<0.01**
% CSW	9.62	9.50	0.12	8.75	8.80	8.84	9.82	9.94	9.61	10.04	9.76	10.16	9.91	0.28	0.63	0.48	**<0.01**	<0.01	**0.04**
Plate, kg	14.73	15.37	0.30	5.19	7.07	9.09	12.35	14.54	18.24	18.89	20.45	20.43	24.32	0.72	0.79	0.13	**<0.01**	<0.01	**<0.01**
% CSW	8.66	8.35	0.14	6.28	6.98	7.45	8.32	8.62	9.29	9.58	9.60	9.16	9.76	0.34	0.95	0.13	**<0.01**	<0.01	**<0.01**
Loin, kg	24.44	26.15	0.32	11.80	15.82	18.07	22.10	24.56	28.62	29.79	31.42	32.51	38.29	0.77	0.26	**<0.01**	**<0.01**	<0.01	**0.02**
% CSW	14.96	14.92	0.15	15.00	15.54	14.85	14.94	14.59	14.62	15.09	14.73	14.60	15.44	0.36	0.78	0.82	0.40	-	-
Flank, kg	10.90	11.84	0.32	3.62	5.88	6.35	8.77	10.88	14.23	13.96	16.86	15.29	17.86	0.76	0.88	**0.04**	**<0.01**	<0.01	**0.01**
% CSW	6.41	6.43	0.14	4.48	5.84	5.20	5.93	6.52	7.28	7.08	7.91	6.83	7.10	0.34	0.91	0.93	**<0.01**	<0.01	**<0.01**
Round, kg	38.61	41.06	0.57	21.93	27.13	31.55	36.06	39.54	45.30	46.67	46.26	49.46	54.40	1.30	0.67	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	24.37	24.07	0.20	28.60	26.74	25.99	24.42	23.55	23.24	23.72	21.78	22.15	22.01	0.46	0.27	0.30	**<0.01**	<0.01	**<0.01**

[1]Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control

Table 3.3. Prediction equations for the determination of carcass components and primals as % CSW for steers non-implanted or administered a Revalor-XS[1] implant using DOF as the dependent variable

Item	Linear	Quadratic	Adjusted R^2	RMSE
Fat yield, % CSW	-	$-0.00000136X^2+0.00095788X+0.07476$	0.68	0.04
Bone yield, % CSW	-	$0.00000039X^2-0.00027345X+0.22329$	0.36	0.02
Red meat yield, % CSW	$-0.00024387X+0.64832$	-	0.28	0.05
Leanness[3]	-	$0.00009233X^2-0.05063X+8.97770$	0.66	1.57
Foreshank, % CSW	$-0.00002076X+0.04232$	-	0.14	0.01
Brisket, % CSW	$0.00002162X+0.05026$	-	0.16	0.01
Rib, % CSW	-	$-0.000000138X^2+0.00008897X+0.08577$	0.27	0.01
Plate, % CSW	-	$-0.000000308X^2+0.00020876X+0.06099$	0.64	0.01
Flank, % CSW	-	$-0.000000265X^2+0.00017128X+0.04511$	0.50	0.01
Round, % CSW	-	$0.000000473X^2-0.00034833X+0.28426$	0.70	0.01

[1]Merck Animal Health, Madison, NJ
[2]Leanness was calculated as the ratio of total muscle to total fat
[3]Muscling was calculated as the ratio of total muscle to total bone

Table 3.4. Effects of Revalor-XS[1] implant administration and days on feed (DOF) on brisket subprimal yields of Charolais × Angus steers

Item[3]	Treatment[2]			Days on feed (DOF)											P-value				
	CON	REV	SEM	0	42	84	126	168	210	252	294	336	378	SEM	TRT× DOF	TRT	DOF	Linear	Quadratic
n	40	40		8	8	8	8	8	8	8	8	8	8						
Brisket, kg	4.27	4.68	0.08	1.94	3.18	3.21	3.74	4.16	5.25	5.52	5.63	5.91	6.22	0.17	**<0.01**	**<0.01**	**0.05**	<0.01	**<0.01**
% CSW	2.65	2.66	0.04	2.49	3.14	2.66	2.51	2.48	2.69	2.78	2.65	2.65	2.53	0.09	0.74	**<0.01**	0.28	-	-

[1]Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control

[3]All subprimals were denuded of external fat before weighing

Table 3.5. Effects of Revalor-XS[1] implant administration and days on feed (DOF) on chuck subprimal yields of Charolais × Angus steers

Item[3]	Treatment[2]			Days on feed (DOF)												*P*-value				
	CON	REV	SEM	0	42	84	126	168	210	252	294	336	378	SEM	TRT× DOF	TRT	DOF	Linear	Quadratic
n	40	40		8	8	8	8	8	8	8	8	8	8						
Arm Roast, kg	2.80	3.03	0.05	1.37	2.04	2.27	2.87	2.96	3.36	3.20	3.33	3.63	4.10	0.12	0.41	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	1.75	1.76	0.02	1.78	2.01	1.87	1.96	1.76	1.73	1.61	1.57	1.63	1.66	0.05	0.12	0.76	**<0.01**	**<0.01**	0.80
Flat Iron, kg	2.13	2.35	0.03	1.03	1.37	1.83	2.04	2.36	2.67	2.43	2.71	2.89	3.08	0.08	0.15	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	1.33	1.35	0.02	1.32	1.34	1.51	1.38	1.41	1.37	1.22	1.27	1.29	1.25	0.04	0.48	0.46	**<0.01**	<0.01	**0.02**
Petite Tender, kg	0.41	0.44	0.01	0.23	0.30	0.37	0.42	0.45	0.45	0.47	0.49	0.50	0.55	0.02	0.24	**0.02**	**<0.01**	<0.01	**<0.01**
% CSW	0.26	0.26	0.01	0.30	0.29	0.31	0.29	0.27	0.23	0.24	0.24	0.22	0.22	0.01	0.19	0.57	**<0.01**	**<0.01**	0.79
Chuck Eye Roll, kg	5.56	6.14	0.10	3.19	3.62	4.54	5.40	6.58	6.84	6.42	6.57	7.28	8.05	0.23	0.25	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	3.50	3.58	0.06	4.12	3.57	3.75	3.67	3.90	3.52	3.22	3.09	3.26	3.27	0.01	0.82	0.30	**<0.01**	**<0.01**	0.58
Mock Tender, kg	1.27	1.37	0.02	0.72	0.98	1.12	1.36	1.47	1.72	1.38	1.33	1.49	1.64	0.06	0.74	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	0.82	0.82	0.01	0.95	0.96	0.93	0.93	0.88	0.88	0.69	0.63	0.67	0.67	0.03	0.49	0.97	**<0.01**	**<0.01**	0.13
Pectoral Meat, kg	0.70	0.75	0.03	0.75	0.58	0.64	0.80	0.69	0.66	0.65	0.77	0.76	0.98	0.07	0.70	0.21	**0.01**	<0.01	**0.02**
% CSW	0.48	0.49	0.02	1.00	0.57	0.51	0.54	0.42	0.35	0.32	0.37	0.34	0.40	0.04	0.52	0.64	**<0.01**	<0.01	**<0.01**

[1]Merck Animal Health, Madison, NJ
[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control
[3]All subprimals were denuded of external fat before weighing

Table 3.6. Effects of Revalor-XS[1] implant administration and days on feed (DOF) on rib subprimal yields of Charolais × Angus steers

Item[3]	Treatment[2]			Days on feed (DOF)												P-value				
	CON	REV	SEM	0	42	84	126	168	210	252	294	336	378	SEM	TRT× DOF	TRT	DOF	Linear	Quadratic
n	40	40		8	8	8	8	8	8	8	8	8	8						
Ribeye Roll, kg	5.12	5.55	0.08	2.39	3.26	4.21	4.80	5.42	5.86	5.87	6.41	7.31	7.78	0.19	0.11	**<0.01**	**<0.01**	<0.01	**0.02**
% CSW	3.16	3.16	0.04	3.08	3.20	3.46	3.27	3.22	3.01	2.95	3.02	3.28	3.14	0.09	0.12	0.93	**0.01**	0.18	0.86
Back Ribs, kg	1.32	1.38	0.03	0.74	0.83	1.03	1.18	1.60	1.38	1.39	1.53	1.84	1.96	0.07	**0.05**	0.14	**<0.01**	**<0.01**	0.42
% CSW	0.82	0.81	0.02	0.96	0.81	0.86	0.80	0.95	0.71	0.70	0.72	0.83	0.80	0.04	0.39	0.59	**<0.01**	<0.01	**0.02**
Rib Blade Meat, kg	0.99	1.14	0.04	0.54	0.68	0.77	1.17	1.30	1.16	1.20	1.23	1.24	1.33	0.09	0.61	**0.02**	**<0.01**	<0.01	**<0.01**
% CSW	0.62	0.66	0.02	0.70	0.67	0.64	0.79	0.77	0.60	0.60	0.58	0.56	0.54	0.05	0.14	0.20	**<0.01**	**<0.01**	0.10
Short Ribs, kg	1.61	1.71	0.05	0.64	0.85	1.75	1.72	1.43	1.97	1.85	1.97	1.96	2.44	0.13	0.67	0.13	**<0.01**	<0.01	**0.01**
% CSW	0.99	0.98	0.03	0.81	0.83	1.43	1.19	0.85	1.02	0.94	0.92	0.88	0.98	0.07	0.94	0.84	**<0.01**	0.28	**0.01**

[1]Merck Animal Health, Madison, NJ
[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control
[3]All subprimals were denuded of external fat before weighing

Table 3.7. Effects of Revalor-XS[1] implant administration and days on feed (DOF) on plate subprimal yields of Charolais × Angus steers

Item[3]	Treatment[2]			Days on feed (DOF)												*P*-value			
	CON	REV	SEM	0	42	84	126	168	210	252	294	336	378	SEM	TRT× DOF	TRT	DOF	Linear	Quadratic
n	40	40		8	8	8	8	8	8	8	8	8	8						
Outside Skirt, kg	0.64	0.73	0.02	0.35	0.47	0.55	0.65	0.66	0.75	0.77	0.79	0.85	1.03	0.05	0.42	**<0.01**	**<0.01**	**<0.01**	0.56
% CSW	0.40	0.43	0.01	0.46	0.45	0.45	0.43	0.39	0.39	0.39	0.37	0.38	0.41	0.02	0.32	**0.04**	**0.06**	<0.01	**0.06**
Inside Skirt, kg	1.26	1.38	0.03	0.72	0.80	1.01	1.15	1.40	1.56	1.54	1.55	1.61	1.85	0.06	0.48	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	0.79	0.80	0.01	0.93	0.80	0.84	0.78	0.83	0.81	0.78	0.73	0.72	0.74	0.03	0.38	0.51	**<0.01**	**<0.01**	0.45

[1]Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control

[3]All subprimals were denuded of external fat before weighing

Table 3.8. Effects of Revalor-XS[1] implant administration and days on feed (DOF) on loin subprimal yields of Charolais × Angus steers

Item[3]	Treatment[2]			Days on feed (DOF)												*P*-value			
	CON	REV	SEM	0	42	84	126	168	210	252	294	336	378	SEM	TRT× DOF	TRT	DOF	Linear	Quadratic
n	40	40		8	8	8	8	8	8	8	8	8	8						
Striploin, kg	4.25	4.55	0.08	2.46	3.13	3.65	4.29	4.42	5.05	5.21	4.78	4.99	6.03	0.20	0.51	**0.01**	**<0.01**	<0.01	**<0.01**
% CSW	2.71	2.69	0.04	3.18	3.10	3.00	2.92	2.64	2.59	2.64	2.25	2.24	2.45	0.11	0.63	0.73	**<0.01**	**<0.01**	0.20
Tenderloin	2.13	2.33	0.03	1.25	1.47	1.78	1.98	2.21	2.52	2.59	2.60	2.76	3.19	0.08	0.31	**<0.01**	**<0.01**	<0.01	**0.05**
% CSW	1.35	1.37	0.02	1.64	1.45	1.47	1.34	1.31	1.29	1.32	1.22	1.24	1.30	0.04	0.53	0.29	**<0.01**	<0.01	**<0.01**
Top Sirloin Butt, kg	3.64	3.95	0.07	2.03	2.54	2.98	3.47	3.85	4.24	4.37	4.37	4.75	5.37	0.15	0.89	**<0.01**	**<0.01**	<0.01	**0.02**
% CSW	2.28	2.32	0.03	2.64	2.50	2.45	2.36	2.29	2.18	2.21	2.05	2.13	2.17	0.06	0.72	0.37	**<0.01**	<0.01	**<0.01**
Top Sirloin Butt Cap, kg	1.37	1.55	0.04	0.68	0.76	1.12	1.37	1.57	1.73	1.79	1.78	1.76	2.03	0.09	0.69	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	0.84	0.89	0.02	0.87	0.76	0.92	0.93	0.93	0.88	0.90	0.83	0.79	0.82	0.05	0.91	0.11	0.13	-	-
Bottom Sirloin Ball Tip, kg	0.24	0.31	0.03	0.20	0.17	0.17	0.19	0.25	0.24	0.23	0.43	0.47	0.40	0.08	0.41	0.20	**0.04**	**<0.01**	0.26
% CSW	0.15	0.18	0.02	0.27	0.17	0.14	0.13	0.15	0.13	0.11	0.20	0.21	0.17	0.04	0.58	0.25	0.24	-	-
Bottom Sirloin Tri Tip, kg	1.13	1.26	0.02	0.62	0.78	0.95	1.04	1.24	1.38	1.43	1.29	1.51	1.68	0.06	0.17	**<0.01**	**<0.01**	<0.01	**0.01**
% CSW	0.71	0.73	0.01	0.80	0.77	0.79	0.70	0.74	0.71	0.73	0.60	0.67	0.68	0.03	0.26	0.43	**<0.01**	**<0.01**	0.40
Hanging Tender, kg	0.47	0.51	0.03	0.26	0.43	0.40	0.47	0.46	0.54	0.58	0.58	0.52	0.66	0.07	0.73	0.30	**0.01**	**<0.01**	0.38
% CSW	0.29	0.30	0.02	0.32	0.41	0.33	0.31	0.27	0.27	0.29	0.27	0.23	0.26	0.04	0.64	0.70	**0.10**	**<0.01**	0.62

[1]Merck Animal Health, Madison, NJ
[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control
[3]All subprimals were denuded of external fat before weighing

Table 3.9. Effects of Revalor-XS[1] implant administration and days on feed (DOF) on flank subprimal yields of Charolais × Angus steers

Item[3]	Treatment[2]			Days on feed (DOF)												*P*-value			
	CON	REV	SEM	0	42	84	126	168	210	252	294	336	378	SEM	TRT× DOF	TRT	DOF	Linear	Quadratic
n	40	40		8	8	8	8	8	8	8	8	8	8						
Bottom Sirloin Flap, kg	1.72	1.89	0.04	0.86	1.09	1.36	1.58	1.88	2.19	2.02	2.13	2.21	2.71	0.10	0.61	**<0.01**	**<0.01**	<0.01	**0.03**
% CSW	1.06	1.08	0.02	1.09	1.07	1.11	1.07	1.11	1.12	1.02	1.00	0.99	1.08	0.04	0.62	0.48	0.28	-	-
Flank Steak, kg	0.88	0.96	0.02	0.56	0.66	0.66	0.82	0.90	1.10	1.04	1.05	1.09	1.32	0.06	0.97	**0.01**	**<0.01**	**<0.01**	0.42
% CSW	0.55	0.57	0.02	0.73	0.65	0.54	0.56	0.53	0.56	0.52	0.49	0.49	0.53	0.04	0.36	0.28	**<0.01**	<0.01	**0.01**
Elephant Ear, kg	1.95	2.12	0.07	0.47	1.29	1.49	1.77	2.09	2.68	2.34	2.52	2.12	3.60	0.15	0.67	**0.08**	**<0.01**	<0.01	**0.02**
% CSW	1.17	1.17	0.03	0.58	1.29	1.23	1.21	1.24	1.38	1.19	1.18	0.95	1.44	0.08	0.58	0.88	**<0.01**	<0.01	**<0.01**

[1]Merck Animal Health, Madison, NJ
[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control
[3]All subprimals were denuded of external fat before weighing

Table 3.10. Effects of Revalor-XS[1] implant administration and days on feed (DOF) on round subprimal yields of Charolais × Angus steers

Item[3]	Treatment[2]			Days on feed (DOF)											P-value				
	CON	REV	SEM	0	42	84	126	168	210	252	294	336	378	SEM	TRT× DOF	TRT	DOF	Linear	Quadratic
n	40	40		8	8	8	8	8	8	8	8	8	8						
Top Round, kg	8.32	8.89	0.14	5.23	6.10	7.08	7.94	8.64	9.94	10.18	9.39	9.98	11.60	0.31	0.79	**<0.01**	**<0.01**	<0.01	**<0.01**
% CSW	5.32	5.30	0.06	6.88	6.00	5.83	5.38	5.16	5.11	5.17	4.43	4.47	4.70	0.13	0.45	0.75	**<0.01**	<0.01	**<0.01**
Eye of Round, kg	2.10	2.33	0.05	1.26	1.52	1.80	2.19	2.15	2.55	2.61	2.42	2.62	3.02	0.11	0.50	**<0.01**	**<0.01**	<0.01	**0.01**
% CSW	1.34	1.37	0.02	1.65	1.51	1.48	1.49	1.28	1.31	1.32	1.13	1.17	1.22	0.05	0.74	0.36	**<0.01**	<0.01	**0.05**
Bottom Round, kg	4.99	5.39	0.09	3.01	3.66	4.28	4.80	4.95	5.91	6.07	5.67	6.33	7.24	0.21	0.33	**<0.01**	**<0.01**	**<0.01**	0.07
% CSW	3.19	3.19	0.05	3.95	3.62	3.52	3.26	2.95	3.03	3.09	2.67	2.84	2.94	0.12	0.21	0.93	**<0.01**	<0.01	**<0.01**
Sirloin Tip, kg	4.90	5.27	0.12	3.08	3.68	4.44	4.96	4.92	5.84	6.01	5.53	5.62	6.80	0.26	0.52	**0.03**	**<0.01**	<0.01	**0.01**
% CSW	3.17	3.15	0.05	4.05	3.62	3.68	3.37	2.94	3.00	3.05	2.60	2.51	2.75	0.12	0.47	0.81	**<0.01**	<0.01	**0.01**
Heel Meat, kg	2.19	2.22	0.08	1.48	1.61	1.88	2.12	2.10	2.38	2.47	2.32	2.91	2.77	0.17	0.67	0.74	**<0.01**	**<0.01**	0.51
% CSW	1.41	1.34	0.03	1.93	1.59	1.55	1.44	1.25	1.23	1.25	1.09	1.31	1.12	0.08	0.47	0.20	**<0.01**	<0.01	**<0.01**

[1]Merck Animal Health, Madison, NJ
[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control
[3]All subprimals were denuded of external fat before weighing

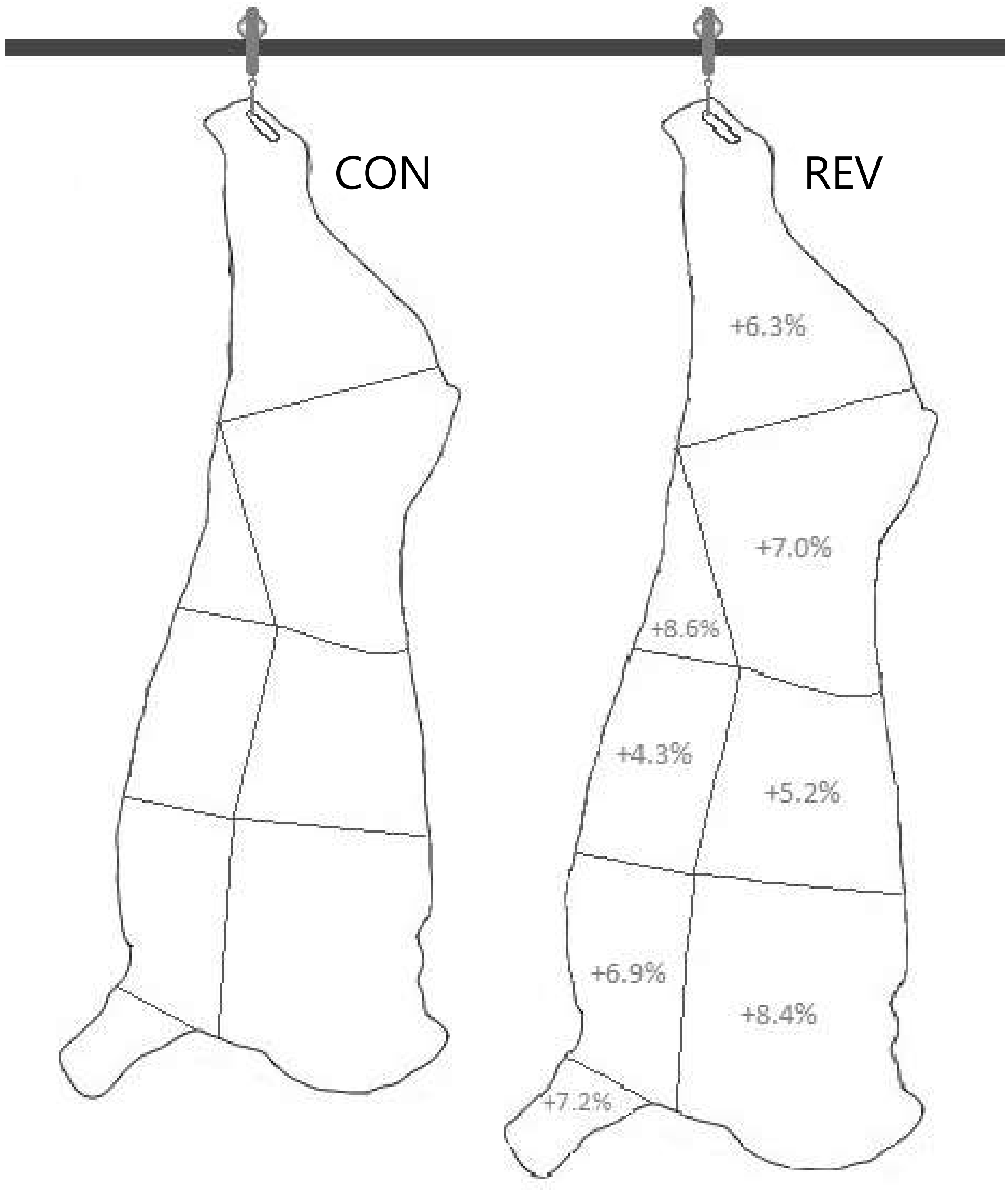

Figure 3.1. Percentage change of carcass primal weights from non-implanted (CON) to implanted (REV) Charolais × Angus steers serially marketed at various end points

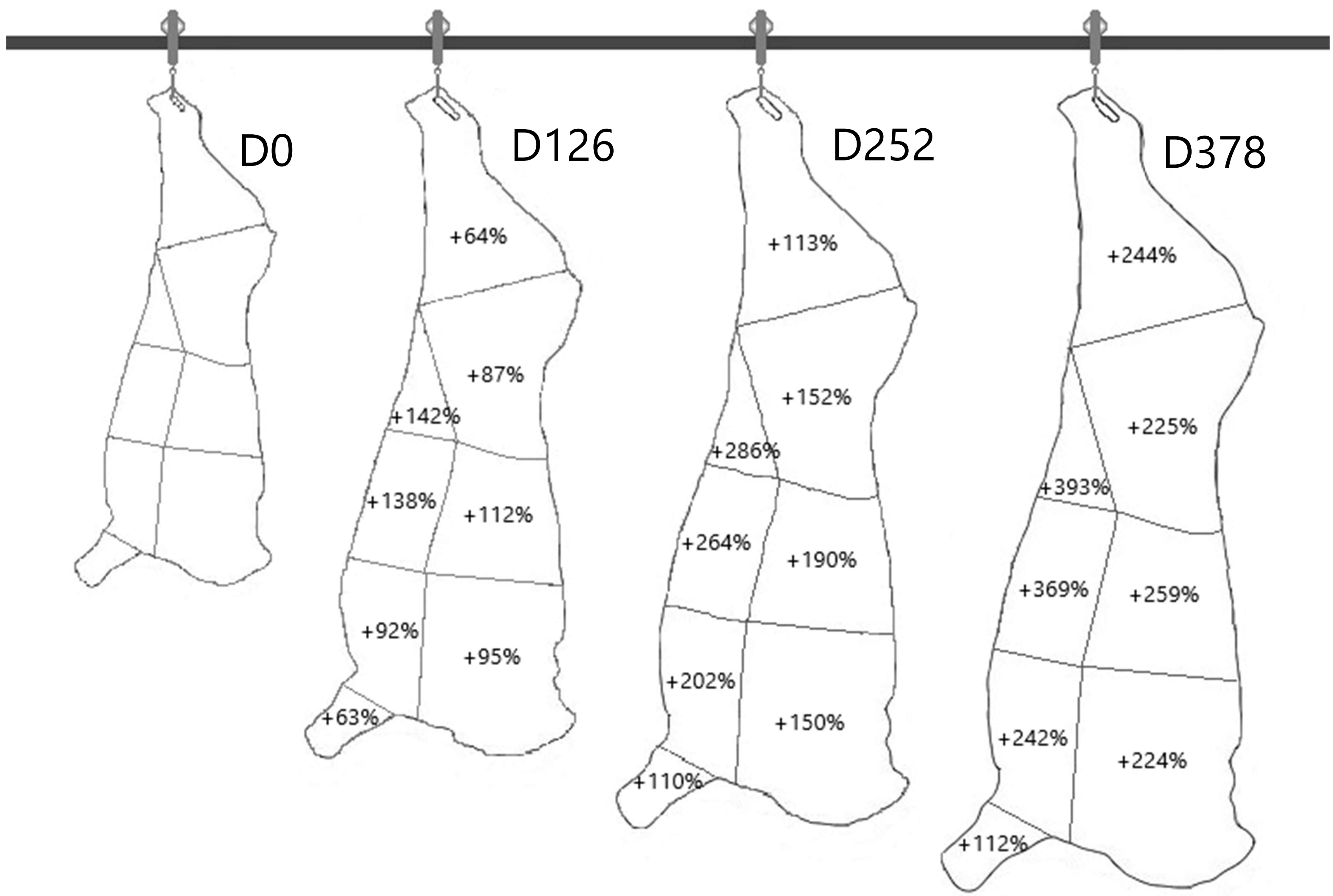

Figure 3.2. Percentage change of carcass primal weights of Charolais × Angus steers serially harvested at marketing endpoints from d 0 to d 126, 252 and 378

CHAPTER 4

ALLOMETRIC GROWTH COEFFICIENTS OF NON-CARCASS AND CARCASS COMPONENTS OF SERIALLY HARVESTED IMPLANTED AND NON-IMPLANTED STEERS

4.1. Abstract

The objective of this study was to quantify allometric growth coefficients of non-carcass and carcass components of implanted or non-implanted Charolais×Angus steers in relation to empty body weight. Steers (n=80; initial BW 271±99 kg) were paired, randomized to harvest date (d 0-42-84-126-168-210-252-294-336-378), and individuals within pairs were randomized to CON (negative control) or REV (Revalor-XS on d 0 and 190) treatments. Weights (g) of non-carcass and carcass components were log transformed and consolidated to arithmetic means by treatment and harvest date. Growth coefficients were calculated using the allometric equation $Y=bX^a$, which when log transformed is represented as Y=b+aX where Y= log(non-carcass or carcass component), X= log(EBW), a= log(slope), and b= log(intercept); the empty body grows at a rate of 1. Treatment outcomes were compared via independent t-test. Tendencies for faster growth of REV steers were detected in non-carcass components for the kidney (*P* = 0.06) and lungs/trachea (*P* = 0.09). Non-carcass components with lowest growth coefficients included small intestine (0.02), large intestine (0.12), and brain and spinal cord (0.13). However, kidney-pelvic-heart fat (2.01) accumulated at more than 2 times the rate of the

empty body, whereas cod fat (1.42) and GIT fat (1.61) grew notably faster than the empty body. Growth coefficients were greater ($P < 0.01$) for REV in two carcass components (chuck eye roll, eye of round), whereas CON was greater ($P < 0.01$) in one component (flank steak). Although not significant ($P > 0.62$), growth coefficients of carcass primals were greater for REV steers with exception of the rib. All primals except the round (0.81) and foreshank (0.87) exhibited growth coefficients greater than the empty body (flank, 1.47; plate, 1.45; brisket, 1.18; rib, 1.18; loin, 1.04; and chuck, 1.03). Conversely, pectoral meat (0.19), bottom sirloin flap (0.56), heel meat (0.59), sirloin tip (0.66), and mock tender (0.69) subprimals all exhibited growth coefficients notably less than the empty body. Although not significant, total lean was deposited more quickly in REV steers (0.95 vs 0.88; $P = 0.45$), whereas total fat (2.17 vs 1.98; $P = 0.35$) and total bone (0.92 vs 0.75; $P = 0.29$) were faster growing for CON steers. These data indicate total body fat exhibited the greatest growth coefficients compared to empty body. Whereas, there were minimal differences in growth coefficients of steers in regards to treatment.

4.2. Introduction

Allometric growth, a term first developed by Huxley and Teissier (1936), refers to growth of a part in relation to the whole, represented by $y=bx^a$. Where y represents the scale of difference or piece, x is whole body size, a is a constant differential growth ratio, and b is a slope for the ratio of y:x (White and Gould, 1965; Gayon, 2000). Differences in relative growth have been speculated to be effected by nutrition, ratio of muscle to bone, genetics, and amount of fat distribution (Butterfield, 1966). Berg and Butterfield (1966) reported that early maturing muscle groups, such as those most distal from the trunk, exhibited fastest growth rates, whereas late maturing groups, such as those most proximal to the trunk, grew slowest. Similarly, Hammond and Appleton (1932) quantified growth gradients in lambs, and reported limbs most proximal to the trunk grew at the slowest rates, whereas those distal to the trunk grew fastest from birth to weaning in comparison to the cannon bone. Growth rates of lean, fat, and bone are not similar and even within component are not the same (Berg and Butterfield, 1968).

Implants have been shown to increase deposition of lean tissue and decrease fat deposition in the carcass (Bruns et al., 2005) and increase overall live weight (Samber et al., 1996). Research has shown the estrogenic portion of the implant enhances sensitivity of muscle and liver cells to growth factors such as serum growth hormone and insulin-like growth factor 1. Conversely, the androgenic portion of the implant blocks cortisol receptors in the muscle cells, leading to decreased muscle degradation. These steroid hormones create an additive effect, increase muscle satellite cell activity, and increase the deposition rate while decreasing the degradation rate of protein (Preston, 1999).

We hypothesize an increase in carcass lean components and a decrease in fat accretion in animals administered growth-promoting implants. The objective of this study was to evaluate the allometric effects of growth-promoting implants on carcass and non-carcass components.

4.3. Materials and methods

4.3.1. Live cattle and carcass procedures

All experimental procedures were approved by the West Texas A&M University Institutional Animal Care and Use Committee. Steers were housed at AgriResearch Feedlot in Canyon, TX.

Charolais × Angus steers (n = 80; 271.2 ± 99.3 kg) were paired within genetic group based on estimated final BW, frame score, and days to target body weight. Pairs were randomly assignment to harvest date at 42-d intervals of d 0, 42, 84, 126, 168, 210, 252, 294, 336, or 378. Individuals within pairs were randomly assigned to CON (negative control) or REV (Revalor-XS, Merck Animal Health, Madison, NJ; administered on d 0 and 190; Kirkpatrick, 2020). Non-carcass components, viscera, and thoracic organs were weighed immediately after removal from carcass during harvest, were allowed to chill 24-h, then were emptied, cleaned, and weighed (Pillmore, 2020). Carcasses were allowed to chill 48-h and fabricated according to industry standards (Wesley, 2020).

4.3.2. Statistical analysis

The original allometric model of Huxley and Teissier (1932), $y=ax^b$ commonly represents a curvilinear relationship, but throughout time has been log transformed to achieve a linear relationship. Coefficient b in the transformed allometric growth equation was calculated as the slope of log y (represented by size of piece) to log x (represented by empty body weight). Mean estimates for treatment were calculated by the slope of the individuals in each treatment, whereas the overall means were calculated using the slope of all individual data. Components exhibiting growth rates greater than one were considered to grow at a rate faster than the empty body, whereas components growing less than one were considered to grow at a rate slower than the empty body. Data were averaged by treatment for each harvest date and the TTEST procedure of SAS was utilized to compare differences between treatments. Differences were detected at $\alpha \leq 0.05$, tendencies $0.05 < \alpha \leq 0.10$, and no difference was acknowledged at $\alpha > 0.10$.

4.4. Results and discussion

4.4.1. Non-carcass components

Tendencies for difference were detected for non-carcass components (Table 4.1) from REV steers to grow at a greater rate than CON in the kidneys ($P = 0.06$) and the lungs/trachea ($P = 0.09$). No other treatment differences were detected ($P \geq 0.13$) in non-carcass components and viscera. Kidney-pelvic-heart fat (KPH) deposition rate did not differ ($P = 0.42$) between implanted and non-implanted animals, although Pillmore (2020) reported implanted steers exhibited a decrease in KPH weight. Although not significant ($P = 0.77$), the rate of deposition for the hot carcass weight (HCW) was faster for implanted steers, indicating the implanted animals grew carcass components at a faster rate than non-implanted steers. Few researchers have quantified differences in growth rates of non-carcass components in implanted or non-implanted steers.

Growth rates for all non-carcass components are shown in Figure 4.1. Kidney-pelvic-heart (KPH) fat accumulated as the fastest growing non-carcass component (2.01), with growth more than two times the empty body. Gastrointestinal (GIT) fat and cod fat were deposited at rates greater than the empty body (1.61 and 1.42, respectively). May et al. (1992) indicated an increasing linear effect on fat thickness and a quadratic increase in KPH fat as steers increased days on feed. May et al. (2017) also reported a quadratic increase in fat yield as a % CSW. Previous findings agree with those in the current study, suggesting fat is deposited at a greater rate than the empty body.

Non-carcass components exhibiting slowest rates of growth were observed in the large intestine and the brain/spinal cord (0.12 and 0.13, respectively). Brain size has been observed and deemed similar between transgenic and giant mice, in either case the brain showed no growth over time (Shea et al., 1987). There was no difference in growth of the large intestine from the period of postweaning to adulthood in mice (Palou et al., 1982). Similarly, Moallem et al. (2004) reported the rumen, reticulum, and omasum to grow at a much faster rate than the intestines, as these organ efficacies were effected by amount and rate of feed intake, whereas the abomasum and intestines grow based on changes in metabolic requirements. Small intestine growth occurred at a rate of 0.02, indicating there was essentially no growth in the small intestine from d 0 to harvest. Relative weight of the small intestines has previously been noted to increase immediately after weaning and then stop growing in size for the remainder of the animal's life (Herbst and Sunshine, 1969; Sharman et al., 2013). Metatarsals/metacarpals grew at a rate of 0.49 of the empty body, indicating the limbs grew at a rate slower than the empty body. These results concur with Butterfield and Berg (1966) who reported the limbs grew at a similar rate to the empty body throughout the animals entire lifespan, however the fastest growth occurred from birth to weaning, and very little thereafter. Steers in the current study were placed on the study only several days after being weaned, causing a similar low growth impetus for the same time frame observed by Butterfield and Berg (1966).

Numerically, the pituitary gland grew faster in implanted steers (0.71) than non-implanted steers (0.56). Estrogenic growth promotants have been consistently shown to increase overall weight of the pituitary gland by increasing somatotropin production in the anterior pituitary (Trenkle, 1970). Conversely, Katz et al. (1969) reported direct implantation of somatotropin into various areas of the brain resulted in a decrease in the size of the anterior pituitary, which likely began to atrophy because of supplied hormones with no need to produce more. Thomson et al. (1996) reported no difference in size of the anterior pituitary after a relatively short implant period, but with a marked increase in number of cells that produce somatotropin.

4.4.2. Carcass components, primals, and subprimals

Growth of carcass components were greater ($P = 0.01$) for REV in the chuck eye roll and eye of round, whereas CON exhibited a faster ($P = 0.01$) growth rate for flank steak (Table 4.2). Tendencies ($P = 0.06$) were observed for heel meat and rib blade meat to grow faster for REV steers. No other differences ($P \geq 0.11$) were observed in components. Previous literature in the area of carcass subprimal growth in relation to the empty body weight is limited. Fabricated carcass yield data (Wesley, 2020) suggested fat were most readily deposited in the rib and plate (Appendix E), whereas implanted steers were more likely to deposit greater amounts of fat in the round (Appendix B), potentially accounting for observed differences in the eye of round and heel meat growing faster for REV steers. These data lead us to believe there are minimal differences in growth rate of individual carcass components between implanted and non-implanted steers.

Total carcass fat was observed to have the fastest rate of growth at 2.07 times the empty body (Figure 4.2). Owens et al. (1995) reported energy is increasingly partitioned to fat deposition as an animal approaches maturity, because fat accretion utilizes less energy to maintain than protein accretion, which requires frequent and energetically expensive protein turnover. Carcass fat percentage has been observed lower in implanted steers than non-implanted steers (Kellermeier et al., 2009), often accompanied by an increase in percentage of carcass protein in implanted steers (Perry et al., 1991; Hutcheson et al., 1997). Total carcass lean was deposited at 0.92 times the rate of the empty body, indicating similar deposition rates to the empty body. Conversely, total carcass fat was the slowest growing component being deposited at 0.84 times the rate of the empty body. Total body fat was also calculated using the sum of GIT, KPH, and cod fat from non-carcass components and total carcass fat from carcass components. Total body fat was deposited at 1.92 times the rate of the empty body. These results indicate total carcass fat accrued the fastest, at almost 200% the rate of the empty body, whereas a lesser portion of growth was attributed to lean, and the smallest portion of carcass growth was attributed to total carcass bone.

Dorsal primals had the fastest growth rates, whereby the flank, plate, and brisket exhibited growth rates of 1.47, 1.45, and 1.18 times that of the empty body, respectively. Priyanto et al. (2009) also reported the plate, rib, and brisket exhibited the fastest growth rates in relation to the empty body. In contrast, the round (0.81) and foreshank (0.87) were the only primals noted to grow slower than the empty body, similar to Hammond and Appleton (1932) and Butterfield and Berg (1966).

Highest growth coefficients were quantified in the elephant ear (1.44), short ribs (1.10), and the top sirloin butt cap (1.05) subprimals. Additionally, subprimals with growth rates similar to the empty body were observed in the ribeye roll (1.02), bottom sirloin flap (1.02), brisket (1.01), and the flat iron (0.99). Conversely, pectoral meat exhibited the slowest rate of growth (0.19), followed by the bottom sirloin ball-tip (0.56), mock tender (0.69), hanging tender (0.73) and subprimals of the round, heel meat (0.59), knuckle (0.66), top round (0.70), bottom round (0.74), and eye of round (0.75). Butterfield and Berg (1966) classified muscles in the distal pelvic limb as a low growth impetus. Hammond and Appleton (1932) classified the same groups of muscles as very late maturing. Very late maturing muscle groups, such as those in the round, would experience the slowest rates of growth and fat accumulation.

4.5. Implications

Minimal differences were observed between growth rates of individual components between implanted and non-implanted steers. Lungs/trachea and kidney weights tended to grow faster for REV steers. No differences were observed in growth of carcass primals. Chuck eye roll and eye of round grew faster for REV, whereas flank steak was faster growing in CON. Tendencies were observed for rib blade meat and heel meat to grow faster for REV. Although not significant, lean was deposited more quickly in REV steers, whereas total fat and total bone were faster growing for CON steers.

The majority of non-carcass components exhibited growth rates less than the empty body. Small and large intestines exhibited the slowest rates of growth, indicating almost no growth in intestines from the start of the study to harvest. Conversely, GIT and cod fat were deposited at rates 1.5 times that of the empty body, and KPH was deposited at 2 times the rate of the empty body. Growth coefficients for all primals except the round and foreshank exhibited coefficients greater than the empty body. Notably, the flank and plate grew at almost 1.5 times the rate of the empty body. In both the non-carcass and carcass components, fat was consistently the fastest growing component, being deposited at two times the rate of the empty body. These data indicate total body fat exhibited the greatest growth coefficients compared to the empty body.

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Table 4.1. Allometric growth coefficients of non-carcass components and organs relative to growth of the empty body of Charolais × Angus steers not implanted or administered Revalor-XS[1] implant

	Treatment[2]		
Item	CON	REV	*P*-value
n	40	40	
Metatarsals/Metacarpals	0.52	0.48	0.89
Hide/Ears/Tail Switch	0.69	0.73	0.92
Pizzle	0.70	0.52	0.15
Head[3]	0.60	0.65	0.15
Brain/Spinal Cord	0.09	0.17	0.42
Pituitary gland	0.56	0.71	0.82
Trimmed Tongue	0.72	0.72	0.92
Lips	0.90	0.90	0.73
Gallbladder	1.01	0.97	0.79
Liver	0.59	0.61	0.97
Esophagus	0.56	0.42	0.16
Spleen	0.92	0.96	0.96
Pancreas gland	0.76	0.83	0.59
Bladder	0.78	0.88	0.13
Rumen	0.73	0.84	0.92
Reticulum	0.37	0.46	0.98
Omasum	0.42	0.61	0.57
Abomasum	0.41	0.45	0.40
Small Intestine	-0.05	0.08	0.84
Large Intestine	0.11	0.13	0.14
Lungs/Trachea	0.46	0.52	**0.09**
Heart	0.83	0.90	0.82
Thymus gland	0.61	0.56	0.37
Kidney	0.51	0.58	**0.06**
Oxtail	0.89	0.97	0.28
GIT[4]	0.42	0.51	0.97
KPH Fat	2.11	1.97	0.42
GIT Fat	1.69	1.56	0.90
Cod Fat	1.42	1.49	0.46
Hot Carcass Weight	1.03	1.06	0.77
TST[5]	0.48	0.55	0.73

[1]Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered at 0 and 200 d; CON = negative control

[3]Head = sum of skull, head meat, and cheek meat

[4]GIT = sum of esophagus, stomachs, and intestines

[5]TST = sum of esophagus, stomachs, intestines, liver, spleen, and pancreas

Table 4.2. Allometric growth coefficients of carcass components relative to growth of the empty body of Charolais × Angus steers not implanted or administered Revalor-XS[1] implant

Item	Treatment[2] CON	REV	*P*-value
n	40	40	
Brisket, primal	1.14	1.23	0.98
Brisket	0.94	1.08	0.22
Foreshank, primal	0.86	0.89	0.78
Chuck, primal	1.01	1.06	0.74
Arm Roast	0.86	0.92	0.84
Flat Iron	0.93	1.05	0.55
Petite Tender	0.78	0.75	0.11
Chuck Eye Roll	0.82	0.90	**0.01**
Mock Tender	0.64	0.74	0.59
Pectoral Meat	0.26	0.11	0.34
Plate, primal	1.42	1.49	0.62
Outside Skirt	0.86	0.85	0.84
Inside Skirt	0.84	0.92	0.49
Flank, primal	1.45	1.50	0.80
Bottom Sirloin Flap	0.98	1.05	0.49
Elephant Ear	1.40	1.48	0.33
Flank Steak	0.85	0.72	**0.01**
Rib, primal	1.21	1.16	0.22
Ribeye Roll	0.96	1.08	0.12
Back Ribs	0.88	0.88	0.98
Rib Blade Meat	0.79	0.88	**0.06**
Short Ribs	1.10	1.10	0.54
Loin, primal	1.03	1.04	0.74
Hanging Tender	0.74	0.74	0.38
Striploin	0.72	0.79	0.41
Tenderloin	0.80	0.84	0.49
Top Sirloin Butt	0.84	0.84	0.11
Top Sirloin Butt Cap	1.05	1.03	0.71
Bottom Sirloin Ball-Tip	0.49	0.57	0.95
Bottom Sirloin Tri-Tip	0.78	0.96	0.21
Round, primal	0.79	0.83	0.66
Top Round	0.68	0.71	0.16
Sirloin Tip	0.60	0.72	0.57
Bottom Round	0.70	0.77	0.22
Eye of Round	0.69	0.80	**0.01**
Heel Meat	0.58	0.61	**0.06**
Total Lean	0.88	0.95	0.45
Total Fat	2.17	1.98	0.35
Total Bone	0.92	0.75	0.29
Total Body Fat[3]	1.97	1.89	0.32

[1]Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered at 0 and 200 d; CON = negative control

[3]Total body fat is the summation of KPH, GIT, and cod fat in non-carcass components and total fat in carcass components

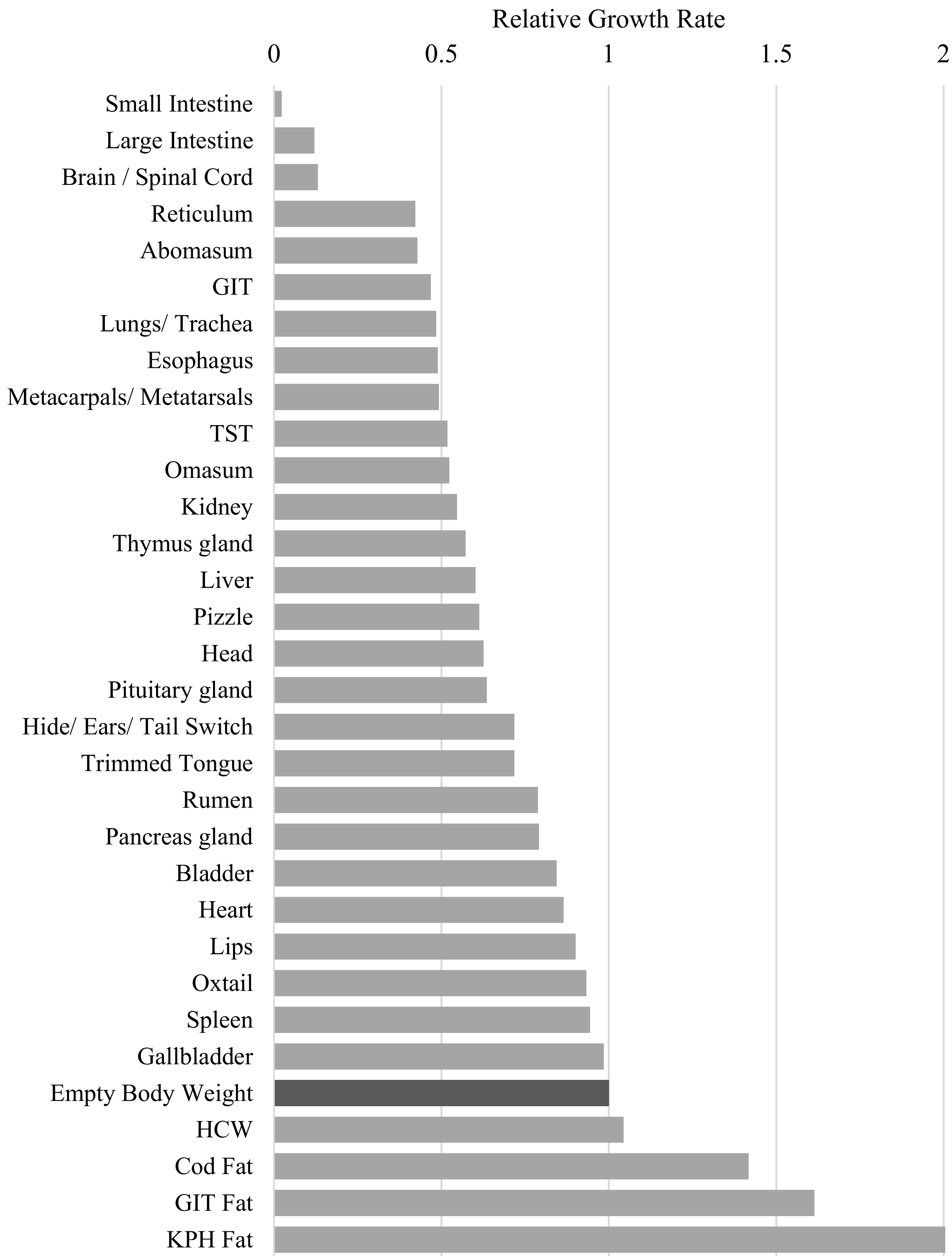

Figure 4.1. Growth of non-carcass components and organs relative to growth of the empty body of Charolais × Angus steers

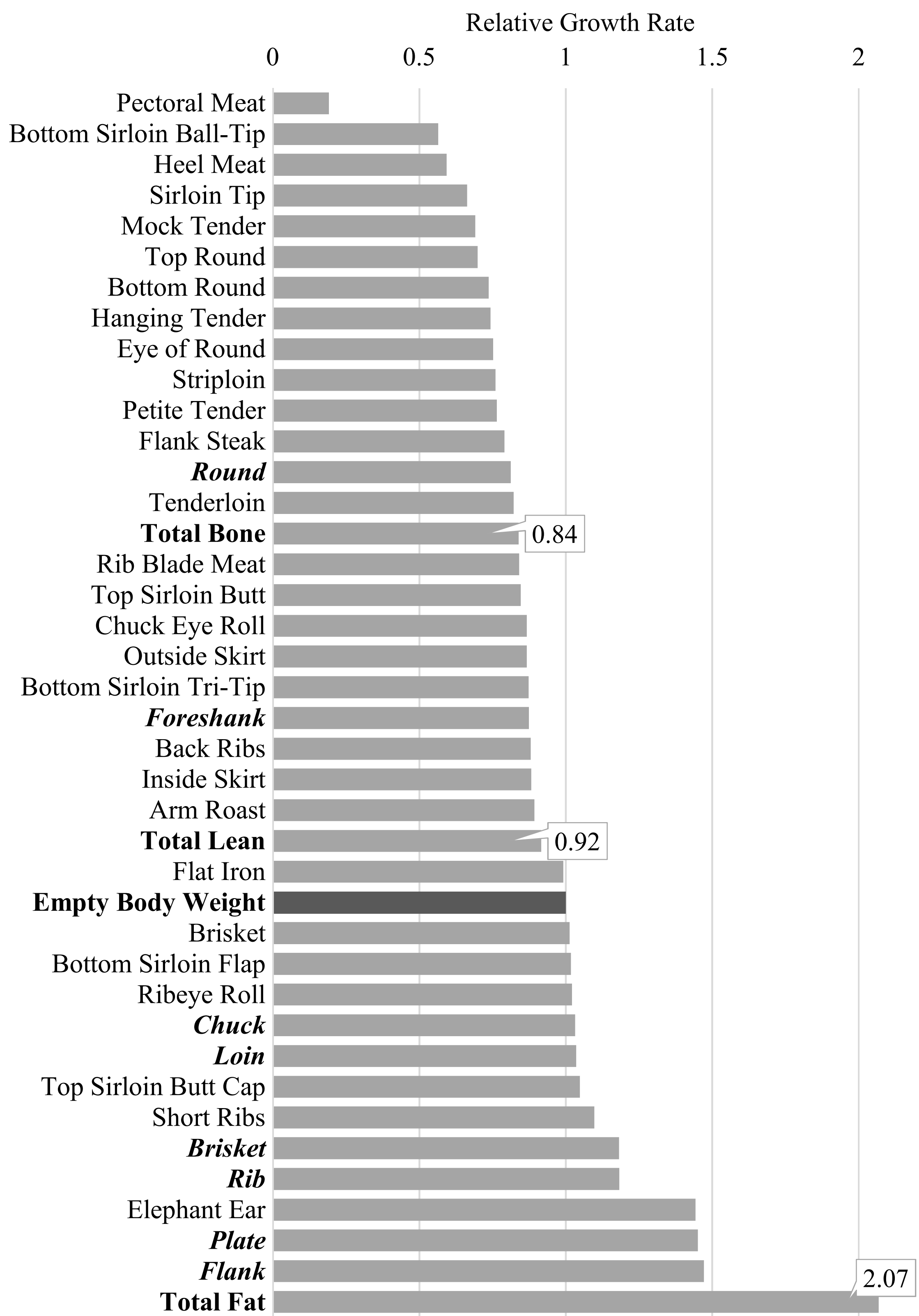

Figure 4.2. Growth of carcass components relative to growth of the empty body of Charolais × Angus steers; regular text = subprimals, ***italic bold*** = primals, and **bold** = carcass components

CHAPTER 5

ECONOMIC ANALYSIS OF IMPLANTED OR NON-HORMONE TREATED STEERS AT VARIOUS MARKET ENDPOINTS FOR PRODUCER AND PROCESSOR RETURN

5.1. Abstract

The objective of this study was to compare the profitability of finished steers produced and processed in either a non-hormone treated (NHTC) or traditional implant program and marketed at various end points. Steers (n=80; Charolais×Angus) were paired by genetic group, estimated finished body weight, frame score, and d to target BW. Pairs were randomized to harvest date (d 0-42-84-126-168-210-252-294-336-378) and individuals within pairs were randomized to CON (negative control) or REV (Revalor-XS on d 0, 190). Live, carcass, subprimal, non-carcass drop, and overhead prices were consolidated from USDA Mandatory Price Reports and industry contacts. Data were analyzed via mixed models. Initial cost varied ($P < 0.01$) between treatments as CON steers demanded premiums for NHTC and source verification. Feed costs were similar, and total production costs tended to be greater for CON ($P = 0.09$). Cattle marketed live or in the beef were of greater ($P < 0.01$) value for REV, as no premium was offered for NHTC steers. Quality grade adjustments tended to discount REV more heavily ($P = 0.06$), yield discounts tended to be greater for CON ($P = 0.10$), and weight based grid adjustments were unaffected by treatment ($P = 0.53$). Adjusted carcass value favored CON steers ($P < 0.01$) due to the NHTC premium. When sold on a live, in the beef or grid basis, neither treatment yielded positive return. All variables with exception of initial

cattle cost were different across DOF ($P < 0.01$). Non-carcass drop values were greater ($P = 0.03$) for REV. Boxed beef values were greater ($P < 0.01$) for CON. Processor net returns were calculated by difference in revenue (boxed beef plus non-carcass drop) and expense (overhead [-$190/carcass] plus procurement of the grid purchased carcass). Net return for processors was similar between treatments ($P = 0.65$). These data indicate implanted steers returned greater revenue when marketed on a live or in the beef basis, whereas NHTC steers returned more value when marketed on a grid basis, although neither treatment was profitable. Additionally, there was no difference between treatments in regards to the profitability of beef processors.

5.2. Introduction

More than 92% of cattle receive a growth promoting implant during finishing (NAHMS, 2013), subsequently enhancing animal value (Duckett and Andrae, 2001; Wileman et al., 2009) and reducing production costs by 6.5% (Lawrence and Ibarburu, 2007). This reduction in costs is a direct result of a 20% improvement in average daily gain and enhanced gain to feed efficiency by up to 27% (Duckett and Andre, 2001; Wileman et al., 2009). Conversely, animals not administered exogenous hormones only make up about 0.5% of cattle harvested in the 2011 National Beef Quality Audit (Moore et al., 2012). These animals or carcasses are traditionally marketed to the EU or to niche channels domestically (AMS, 2019). Presence of non-hormone treated cattle (NHTC) in the marketplace at the feeder level increased by more than 450% from 2010 to 2018 on one online marketing platform (McCabe et al., 2019). These non-implanted animals need to receive a premium to offset the reduced production via poorer feed conversion and reduced average daily gain compared to their implanted counterparts.

Profit at harvest is of foremost importance to producers. Producers who market cattle on a live basis are driven by finished body weight, whereas those who market cattle on a grid are concerned with premiums and discounts as well as HCW. Implants have been proven to increase finished body weight 6 to 8% (Guiroy et al., 2002), and increase HCW 3 to 4% (Bruns et al., 2005) compared to non-implanted steers. Cattle in a NHTC program are traditionally lighter, but are eligible for premiums when marketed as feeder calves (from 1.02 to 4.04%, McCabe et al., 2019), stocker calves, and finished cattle sold on a grid basis (average $20/cwt, USDA, 2020).

We hypothesized increased weight gain from implant administration would outweigh premiums received for NHTC. The objective of this study was to evaluate the profitability of various marketing endpoints for cattle marketed via conventional or NHTC programs.

5.3. Materials and methods

5.3.1. Live cattle and carcass procedures

Steers (n = 80; 271.2 ± 99.3 kg) were paired within genetic group, estimated final BW, frame score, and days to target body weight. Pairs were randomized to harvest date at 42-d intervals (0, 42, 84, 126, 168, 210, 252, 294, 336, 378 d), and individuals within pairs were randomized to CON (negative control) or REV (Revalor-XS, Merck Animal Health, Madison, NJ, on 0 and 190 d). Live growth performance and feeding behavior were previously presented in Kirkpatrick (2020). Non-carcass drop components and carcass grading were previously reported by Pillmore (2020). After a 48-h chilling period, carcasses were fabricated according to industry standards (Wesley, 2020).

5.3.2. Determination of producer prices

Initial cattle costs were determined by prices presented in Table 5.1. Steers in the CON treatment received a \$7.50/ 45.4 kg premium (estimated by industry contacts) for initial purchase as a result of value for NHTC source verification. Feed costs were calculated on an individual basis were reported by Kirkpatrick (2020). Miscellaneous fees included yardage (\$0.48/animal/d), loan interest (at 20% equity and 5% interest per year), beef checkoff fees (\$2/animal), TCFA dues (\$0.007/animal/d), insurance fees (\$0.009/animal/d), vaccinations and anthelminthics (\$8.96/animal; except those harvested on d 0, due to withdrawal restrictions), processing fees (\$1.50/chute entry; charged at d 0 and d 190, where all remaining steers were re-vaccinated and/or re-implanted), and implants (\$8.44/animal; expensed to all REV steers once or twice). Freight was charged at \$4/loaded mile for an average distance of 70 miles from the beef processor, or \$8/animal. Freight was charged to cattle producers if cattle were sold on in the beef or grid based methods. All of the above were combined to represent costs to producers during finishing and are presented in Table 5.4.

Live cattle and dressed beef prices were collected from USDA report LM_CT187 "TX-OK-NM Monthly Directly Slaughter Cattle Report" from August 2018 to October 2019 (USDA, 2020a) and consolidated to one value utilized for all DOF endpoints. There are no publically accessible records to quantify the premiums offered for NHTC cattle marketed on a live or in the beef basis, and therefore no premiums were applied for CON steers on these marketing methods. Grid based carcass adjustments for quality grade, yield grade, carcass weight, and quality programs were collected and averaged from USDA report LM_CT155 "National Weekly Direct Slaughter Cattle- Premiums and

Discounts” from August 2018 to October 2019 (USDA, 2020b) and reported in Table 5.2. Premiums for NHTC were $20.16 ± 0.33/cwt on a dressed basis, and dressed base price were $182.79 ± 11.72/cwt for the study period (USDA, 2020b). Expenses from above were subtracted from live, in the beef, or grid revenue to determine net return to cattle producers, presented in Table 5.6.

Premiums were calculated for CON cattle to reach breakeven from NHTC marketing programs at each endpoint and marketing method and presented in Table 5.8. Expenses and revenues were calculated on an individual basis for all CON steers, and the differences were calculated for each marketing channel. Grid based marketing methods were represented as the starting grid value and allowed for adjustments in USDA QG, yield grade, carcass weight, and marketing program.

5.3.3. Determination of processor prices

Adjusted grid values calculated using the information above and a $190/carcass overhead slaughter and fabrication expense (provided by industry contacts) were combined to represent processor expenses. Freight was charged at $8/hd for an average distance of 70 miles from the beef processor, and charged to the beef processors if cattle were sold on a live basis.

Non-carcass drop value was representative of consolidated values from USDA report NW_LS441 “By-Product Drop Value (Steer) for Central U.S.” (USDA, 2020c), and values provided by anonymous industry contacts; individual component weights were reported by Pillmore (2020). Subprimal and trim weights were weighed and reported (Wesley, 2020) on an individual basis. Subprimal yields were collected and consolidated from USDA reports LM_XB452 (USDA, 2020d), LM_XB459 (USDA, 2020e) and LM_XB462 (USDA, 2020f) "National Weekly Boxed Beef Cutout and Boxed Beef Cuts" for Branded, Choice, Select, and Ungraded products, meat and bone meal and edible tallow values were consolidated from USDA Agricultural Marketing Service Custom Reports between August 2018 and October 2019.

Boxed beef cutout prices were not publically available for NHTC cattle, therefore individual percentage change in price from grid value (base grid value and quality adjustments) to boxed beef value were calculated for all animals, then averaged by quality grade. The average percentage change for each quality grade was then applied to the ending grid value (base grid value, quality adjustments, and NHTC premium) for NHTC cattle to represent the boxed beef value for NHTC steers. Percentage change for each quality grade is presented in Table 5.3.

Trim was mixed to achieve 81% ground beef and prices were averaged from USDA report LM_XB459 (USDA, 2020e). Hanging tender, elephant ear, and heel meat values were not presented in USDA report LM_XB459 (USDA, 2020e) and were included in 81% ground beef. Net return to beef processors were calculated as the difference in revenue (subprimal value and non-carcass drop value) and expenses (grid value and overhead costs), and is presented in Table 5.7.

5.3.4. Statistical analysis

A balanced incomplete block design was used with a 2 × 10 factorial treatment arrangement. The MIXED procedure of SAS was utilized to analyze the fixed effects of implant TRT, DOF, and TRT × DOF interaction with d 0 BW as a covariate and random effects of pair. Mean estimates were calculated using LSMEANS. Differences were identified at an $\alpha \leq 0.05$, and tendencies were recognized at $0.05 < \alpha \leq 0.10$. Differences were for linear and quadratic trends in relation to DOF were analyzed using CONTRAST statements, and acknowledged at $\alpha \leq 0.05$.

5.4. Results and Discussion

5.4.1. Producer expenses

For beef producer expenses, tendencies for TRT × DOF interactions were detected in the feed costs and total expenses with and without freight ($P \leq 0.09$; Appendices O, P, and Q), but not in initial or miscellaneous costs ($P \geq 0.15$). This interaction in feed costs is a result of REV steers decreased feed consumption, and therefore feed costs, at d 190 whereas CON steers continued to predictably increase feed costs. Re-implantation on d 190 decreased maintenance costs, and combination implants have been proven to decrease maintenance costs up to 19% (Hutcheson et al., 1997). Guiroy et al. (2002) reported implants improve efficiency of energy consumption, therefore a decrease in intake post-implantation is warranted. Interaction of TRT × DOF for total expenses followed a similar pattern to feed costs, with a decrease for expenses in REV at d 190 and CON remaining constant. Almost half of total expenses from feedlot animals come from feed expenses (Fernández and Woodward, 1999; McEvers et al., 2018).

Initial cattle cost was greater for CON than REV ($1003.13 vs $956.71; $P < 0.01$) due to an additional $7.50/ 45.4 kg cost for NHTC source verification. McCabe et al. (2019) reported calves enrolled in an NHTC program experienced premiums greater than those given to implanted calves for seven years between 2010 and 2018. No difference in initial cost for DOF was detected ($P = 0.99$), as cattle were randomized to harvest date. Feed intake was previously reported in Kirkpatrick (2020), where days on feed exhibited a quadratic relationship ($P < 0.01$) and no difference ($P = 0.15$) was observed between intake of implanted and non-implanted steers. Johnson et al. (1996) reported no difference in dry matter intake during the first 40 d after implantation, then an increase the following 70 d, and lastly no difference in intake at the end of the study. These results were expected after re-implant when at d 210 intake increased as expected, however an unexpected decrease in intake occurred at d 252 confounded by a cold wet weather event and subsequent boggy pen conditions when cattle stood navel deep in mud. Ration costs averaged \$198.17/ 907.2 kg for the study period. Feed costs increased as DOF increased ($P < 0.01$), however feed costs were similar between 210 and 252 DOF, likely due to sloppy pen conditions, and a subsequent decrease in feed intake. Presence of an implant did not affect cost of feeding ($P = 0.14$). Miscellaneous fees were greater ($P < 0.01$) for REV steers, likely due to the implant cost, which CON steers did not receive. Miscellaneous fees were also affected ($P < 0.01$) by DOF, which is a correlation to increased interest and yardage fees.

Expenses were determined by summation of the above information. Total expenses to the beef producer with and without freight were different for all DOF ($P < 0.01$), except d 210 and 252, which had similar expenses likely due to the similarity in feed costs discussed previously. Feed costs, yardage, and interest fees are directly increased with increasing DOF, and therefore these results are expected. McEvers et al. (2018) also reported an increase in overall expenses as animals were fed for longer durations of time. Total expenses with and without freight costs were greater ($P = 0.02$) for CON steers likely due to a higher procurement cost, and subsequent similarities in costs regardless of implant status.

5.4.2. Producer revenue

We simulated cattle marketed in a live, in the beef, or grid basis. All live and grid based adjustment values on a per 45.4 kg basis are presented in Table 5.5. No TRT×DOF interactions ($P \geq 0.26$) were detected for producer revenues.

On a live basis, REV steers returned $89.65/animal more than CON steers ($1474.65 vs $1385.00/animal; $P < 0.01$), due to heavier live weights of implanted steers. Animals administered combination implants have been consistently proven to increase live weights 2 to 11% (Hunt et al., 1991; Johnson et al., 1996; Bruns et al., 2005; Maxwell et al., 2015). Live value per animal was different for all DOF ($P < 0.01$), except for d 210 to 294, likely due to a weather event which caused feed intake to decline, and subsequently causing a similar finished shrunk body weight.

Steers marketed in the beef were $92.87/animal more profitable for REV than CON ($1507.60 vs. $1414.73; $P < 0.01$), due to a greater carcass weight. In the beef value was effected by DOF ($P < 0.01$) and followed an increasing trend similar to live value where differences did not exist between d 84 – 126, 210 – 252, and 294 – 336. Cattle marketed in the beef are sold commonly in areas where mud/manure tagging on the hide is excessive, and these cattle would receive the grid base value for the hot carcass weight only. This method is also commonly referred to as the dressed basis, and is different from the live value only based on dressing percentage of the individual animal (Hogan et al., 2012). Therefore, the relationship between live and in the beef values as observed are warranted.

Starting grid value, as reported as in the beef, was $182.79/45.4 kg and was greater on a carcass basis for REV ($1507.60 vs $1414.73; $P < 0.01$) due to heavier carcasses (Table 5.5). Quality based grid adjustments were made on a per 45.4 kg basis and discounts tended to favor CON (-\$8.95 vs -\$11.54/ 45.4 kg; $P = 0.06$). Traditionally implanted animals tended to have lower quality grades than their non-implanted counterparts as energy is partitioned towards lean deposition (Bartle et al., 1992; Gerken et al., 1995; Johnson et al., 1996; Duckett and Pratt, 2014). Discounts for yield grade based carcass traits tended to be greater for CON than REV steers (-\$3.04 vs -\$1.50/45.4 kg; $P = 0.10$), and was effected by DOF ($P < 0.01$). Between d 0 – 168 steers received premiums for yield grade, whereas after d 195 steers acquired discounts for excessive USDA YG. Increase in yield grade as animals spend more time on feed has been observed (May et al., 1992; Foutz et al., 1997; Kellermeier et al., 2009). Yield grade adjusted discounts were accrued between d 210 – 252, but to a lesser degree than those at d 294 and beyond. Weight based grid adjustments were not effected by TRT ($P = 0.53$), but were effected by DOF ($P < 0.01$). Weight based adjustments remained discounts for the entirety of the study due to lightweight carcass at the beginning of the study and heavyweight carcasses at the end of the study. The heaviest discounts were accounted for at the beginning of the study between d 0 – 42 whereas lesser discounts were observed between d 84 – 336. Grid price per 45.4 kg is inclusive of a \$20.16/ 45.4 kg premium for NHTC cattle applied to all CON steers. Grid value per 45.4 kg was effected by TRT, whereas CON returned \$22.27/ 45.4 kg more than REV cattle ($P < 0.01$), as well as DOF ($P < 0.01$), where greatest value occurred between d 168 – 252. Overall grid values accounting for carcass weight and any grid based adjustments were \$95.67 greater for CON than REV.

These data indicate that REV steers weighed more and returned more revenue on a live and in the beef basis than CON steers, this weight advantage simply could not overcome the premium given to NHTC cattle. Similar studies have indicated implanted steers will weigh more at harvest, but exhibit less desirable quality and yield traits than their non-implanted counterparts (Guiroy et al., 2002). However, some research suggests there is no difference in quality grade in implanted verses non-implanted animals (Thompson et al., 2008; Maxwell et al., 2015). Grid value per carcass was also effected by DOF ($P < 0.01$) where all time points differed, except between d 210 – 294 and d 336 – 378.

5.4.3. Producer net returns

In regards to net return of cattle purchased on live, in the beef, or grid options, no TRT × DOF interactions were observed ($P \geq 0.14$) and are represented in Table 5.6, Figures 5.1, 5.2, and 5.3.

When sold on a live basis, neither treatment yielded positive return, however REV steers lost less money than CON steers (-\$107.36 vs -\$218.33/animal; $P < 0.01$). Cattle sold on a live basis are often less profitable than those sold on a grid basis (Fausti et al., 1998; DiCostanzo and Dahlen, 2000), because they are unable to receive premiums or adjustments. Neither treatment returned profit to the cattle producer at any time point.

Marketed on an in the beef basis including freight expenses, neither treatment yielded a profit, but REV steers returned \$114.17 to the producer over CON (-\$82.41 vs -\$196.58/carcass; $P < 0.01$). This occurred primarily because of the 6.5% increase in hot carcass weight by REV over CON steers. In the beef returns including freight were quadratically effected by DOF ($P < 0.01$) where no DOF endpoint exhibited a positive return. Non-implanted CON steers were not profitable; whereas REV steers briefly reached breakeven between d 182 – 304.

Grid based marketing with freight expenses was effected by TRT where overall neither treatment yielded a profit, but CON was more profitable than REV (-\$176.17 vs -\$250.52/ carcass; $P < 0.01$). Differences observed in grid value was a function of heavier discounts to REV carcasses, noted particularly by the tendency for greater quality-based grid discounts. Net grid return was quadratically effected by DOF ($P < 0.01$). Premiums for NHTC allotted to CON steers allowed them to breakeven between d 167 – 220, whereas REV steers did not return positive profit to the cattle producer when marketed on a grid basis.

The best marketing method was dependent upon treatment, whereas REV steers returned profit when marketed in the beef and CON steers returned profit when marketed on a grid basis. Additionally in Figures 5.1, 5.2, and 5.3, a difference of \$250 - \$500 can be observed between the expenses and revenue from these steers at d 0. These data suggest the cattle producer is either paying too much for these animals as feeder calves, or is not getting paid enough by the beef processor, who is more than able to cover costs of these same animals at d 0 (Figure 5.4).

5.4.4. CON breakeven premiums

Calculated NHTC premiums required for CON steers to reach breakeven are presented in Table 5.8. On a live basis, CON steers would require an average premium of \$25.81/ 45.4 kg in order for the producer to breakeven. Live premium prices are directly affected by DOF ($P < 0.01$), where highest premiums required occur at d 0 and 42, and smallest premium would be needed for CON steers to breakeven between d 84 - 378.

Similar to live marketing methods, in the beef marketing is affected by DOF (P < 0.01). The highest desired premium occurs at d 0 at \$100.52/ 45.4 kg, while a smaller premium is required after d 126 for producers to breakeven. Marketing steers in the beef with freight expenses would need an average premium of \$34.13/ 45.4 kg for producers to breakeven.

Grid based marketing methods inclusive of freight expenses would require average premiums of \$55.65/ 45.4 kg to reach producer breakeven. Marketing cattle on a grid would require producers to receive the greatest premium at d 0 and the lowest premium between d 168 – 378. Quadratic relationships for DOF existed for all premium calculations (P < 0.01).

5.4.5. Processor expenses

Expenses for beef processors included procurement and overhead processing costs, which are presented in Table 5.7. No TRT × DOF interactions existed for processor expenses (P = 0.38). Procurement costs were reflected in grid value to producers and were effected by TRT (P < 0.01) and DOF (P < 0.01). Non-implanted steers were \$95.67 more expensive to acquire than REV steers due largely to NHTC premium costs (\$1435.15 vs \$1339.48/ carcass; P < 0.01). Smith (2007) also noted an increase in value / hd for NHTC animals due to the additional premiums offered at the processor level. Weight is a primary influencer of value for animals purchased on a grid basis (Fausti et al., 1998). This relationship is directly reflected in the current study, as steers had heavier shrunk body weights, they began to receive fewer lightweight carcass discounts and more heavyweight carcass discounts, seen in the weight adjustments for producer grid based marketing. Overhead processing fees for harvest and fabrication were estimated by industry connections at \$190/ carcass. This value is representative of the typical market-ready animal, and does not account for higher and lower overhead fees these steers would have received at the beginning and end of the study, respectively due to drastic differences in carcass size.

5.4.6. Processor revenue

Beef processor revenue was accumulated in non-carcass drop and boxed beef values. No TRT × DOF interactions were observed ($P \geq 0.21$). Non-carcass drop value was effected by TRT ($P = 0.03$) and DOF ($P < 0.01$). Drop value for REV carcasses was \$10.83 more profitable than CON carcasses (\$321.28 vs \$310.45/ carcass), due to heavier shrunk body weight. Byproduct drop values have often been correlated to an increase weight of the animal (AMS, 2020). The most common method of calculating drop credit would be utilizing a USDA report and multiplying the value given by the per 45.4 kg value of the animal, resulting in this direct correlation. The values for non-carcass drop components presented in this study are higher than what a producer would expect to receive. In this study, in addition to the USDA Mandatory Price Reportings, we also calculated prices for items (based on anonymous industry contacts) that have a value to the processor, but often go unreported, in this case the pizzle, pituitary gland, sweetbreads, weasand meat, melts, pancreas, omasum, abomasum, large intestine, and kidneys. Similarly differences for non-carcass drop value in DOF is a result of carcass weight differences, where d 42 – 84 and 168 – 252 were similar and all other time points were different. The greatest revenue occurred at the last time point, and the lowest revenue occurred at the first time point. This is likely attributed to increase in hot carcass weight of steers at the end of the study compared to the beginning. Similar results in non-carcass drop component growth has been observed by (Hutcheson et al., 1997). Boxed beef values were influenced by both TRT ($P = 0.22$) and DOF ($P < 0.01$). Steers administered a growth-promoting implant had heavier carcasses, primal weights, and high-value cuts in the rib and loin (Wesley, 2020). However, processors were able to sell the boxed beef from CON steers at a premium resulting in additional $93.47/carcass over those for REV steers. Boxed beef value was increased at each time point, but was similar between d 210 – 252 and 294 – 336. These differences are attributed to growing carcass weights as well as increased quality grade as DOF increased, which has been documented repeatedly (Hermesmeyer et al., 2000; Platter et al., 2003; Schmitz et al., 2018).

5.4.6. Processor net returns

Returned net value was calculated as the difference in revenue (boxed value + non-carcass drop value) and expenses (grid value + overhead costs) and are shown in Table 5.7 and Figure 5.4. Net return for beef processors were unaffected by TRT × DOF interaction ($P = 0.95$). Unlike producer return, processors experienced positive returns for both treatments and at all time points. Beef processors commonly receive a positive profit regardless of treatment (Sweatt et al., 1996). There was no difference between treatments in processor net returns ($P = 0.64$). Although CON steers required a higher procurement cost initially, they recovered this additional expense when CON boxed beef was able to be sold at a premium to that of REV. Net value was effected by DOF ($P < 0.01$), where greatest return occurred at d 378, whereas d 210 – 252 and 294 – 336 exhibited similar returns, and d 0 – 168 were least profitable. It is important to note there are two primary reservations for producers looking to sell their cattle in the NHTC marketplace. The first being, the additional premiums offered for NHTC steers are only available as a niche product. If the market were to be flooded with NHTC animals, we speculate an accompanied decrease in the premiums. Simply, if the supply for NHTC animals increases substantially and is not accompanied by an increase in demand, the additive supply will diminish in value. Secondly, there are relationships that need to be built with the cattle feeders in order to source these NHTC verified calves and do so at a reasonable price, as well as the beef processors to ensure they are willing to process these animals and market the beef to these niche market channels.

5.5. Implication

As a cattle producer, total expenses tended to be higher for CON steers, solely as a result of greater procurement costs. When marketed live or in the beef, implanted steers returned more revenue than NHTC, as a result of greater live weight. Conversely, steers marketed as NHTC on a grid basis proved more profitable, primarily due to premiums given to these cattle. Although implanted cattle had heavier carcasses and returned more revenue on a live and in the beef basis, the added pounds were simply not enough to overcome the premium given to NHTC cattle on a grid basis. Overall, both treatments experienced losses at the majority of time points and regardless of the marketing channel.

In regards to the beef processor, any TRT and DOF combination will yield a profit. Expenses were highest for CON animals due to NHTC premiums. Revenue was greater from non-implanted animals due to premiums offered in a niche boxed beef market. Net return to the processor was similar between treatments due to a balancing of high procurement and high return for CON steers, as well as a comfortable margin for REV steers. Net return was greatest at the end of the trial when animals were the heaviest.

These data suggest NHTC steers have the potential to return similar or more value to the cattle producer, with similar return to the beef processor compared to implanted steers. However, these conclusions for NHTC animals are assuming a stable supply of these cattle and previously established relationships within the feeder calf and beef processor segments.

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Table 5.1. Prices and expenses accounted for in breakeven analysis

Item	Expense
Cattle price REV, $/45.4 kg	$154.53
Cattle price CON, $/45.4 kg	$162.03
Feed cost[1], $/907.2 kg	$198.17
Miscellaneous Expenses	
Yardage, $/animal/d	$0.48
Medication[2], $/animal	$8.96
Processing[3], $/chute run	$1.50
Implant[4], $/implant	$8.44
Interest Rate[5], %/yr	5.00%
Beef Checkoff, $/animal	$2.00
TCFA Dues, $/animal/d	$0.007
Insurance, $/animal/d	$0.009
Freight, $/animal	$8.00

[1]Feed costs on an as fed basis
[2]Medication includes vaccines and anthelminthics; charged to all animals except those harvested on d 0
[3]Charged once for initial processing or twice for re-vaccination and/or re-implant of all animals remaining at d 190
[4]For all REV steers only, charged once or twice
[5]Interest Rate was 5.00% annually, assuming 20% equity

Table 5.2. Average price[1] during study[2] for live and grid based revenue analysis at $/45.4 kg

Item	Adjustment
Live Basis	$116.53
Dressed Basis	$182.79
Quality	
Premium Choice	$3.75
USDA Choice	$0
USDA Select	($14.57)
USDA Standard	($30.77)
USDA YG	
1.0-2.0	$3.86
2.0-2.5	$1.99
2.5-3.0	$1.63
3.0-4.0	$0
4.0-5.0	($11.52)
5.0+	($17.75)
Weight	
400-500[3]	($30.87)
500-550	($23.14)
550-600	($10.48)
600-900	$0
900-1000	($1.52)
1000-1050	($7.48)
1050+	($20.78)
Marketing Programs	
NHTC	$20.16

[1] Consolidated from USDA MPR LM_CT187

[2] August 2018 to October 2019

[3] Any carcasses under 400 lbs were classified with 400-500

Table 5.3. Percentage change of value[1] from grid to carcass value for all steers

Item	Percent Change
Premium Choice	+124.197%
Choice	+119.252%
Select	+127.737%
Standard	+148.284%

[1]Percentage change of value = boxed beef value per carcass ÷ [(base grid value + quality adjustment) * hot carcass weight]

Table 5.4. Calculated expenses for cattle producers of implanted (REV) or non-implanted (CON) Angus × Charolais steers serially marketed at various end points [1, 2]

	Item	n	Shrunk BW, kg	Cattle Cost[3], \$/animal	Feed Costs, \$/animal	Miscellaneous[4], \$/animal	Total Expenses[5], \$/animal	Total Expenses w/ Freight[6], \$/animal
TRT[1]	CON	40	541	1003.13	455.92	144.25	1603.31	1611.31
	REV	40	572	956.71	469.05	156.26	1582.02	1590.02
	SEM	–	5.57	0.58	7.38	0.41	7.57	7.57
DOF	0	8	271[h]	980.04	0.00[i]	3.50[j]	994.99[i]	1002.99[i]
	42	8	362[g]	979.25	118.64[h]	42.52[i]	1140.43[h]	1148.43[h]
	84	8	420[f]	980.12	216.70[g]	70.16[h]	1266.97[g]	1274.97[g]
	126	8	494[e]	979.26	322.70[f]	99.06[g]	1400.94[f]	1408.94[f]
	168	8	559[d]	979.99	435.98[e]	128.49[f]	1544.51[e]	1552.51[e]
	210	8	635[c]	980.22	576.07[d]	166.47[e]	1722.82[d]	1730.82[d]
	252	8	635[c]	979.51	596.19[d]	195.77[d]	1771.42[d]	1779.42[d]
	294	8	689[b]	979.87	693.56[c]	228.97[c]	1902.41[c]	1910.41[c]
	336	8	716[b]	981.32	783.30[b]	262.21[b]	2026.80[b]	2034.80[b]
	378	8	785[a]	979.64	875.48[a]	300.13[a]	2155.33[a]	2163.33[a]
	SEM	–	12.58	1.31	19.07	1.26	19.55	19.55
P - value	TRT× DOF	–	0.65	0.81	**0.07**	0.15	**0.09**	**0.09**
	TRT	–	**<0.01**	**<0.01**	0.14	**<0.01**	0.02	0.02
	DOF	–	**<0.01**	0.99	**<0.01**	**<0.01**	**<0.01**	**<0.01**
	Lin	–	**<0.01**	0.66	**<0.01**	**<0.01**	**<0.01**	**<0.01**
	Quad	–	**<0.01**	0.89	**0.01**	**<0.01**	**0.03**	**0.03**

[a,b,c,d,e,f,g,h,i] Means in a column with differing superscripts are different

[1]Revalor-XS, Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS 200 mg trenbolone acetate and 40 mg estradiol 17-beta in a proprietary timed release coating) combination implant administered on 0 and 190 d; CON = negative control

[3]Cattle cost at \$154.53/cwt for REV, and an additional \$7.50/cwt premium for CON calves

[4]Miscellaneous costs included yardage (\$0.48/animal/d), vaccines and antihelmenthics (\$8.96/animal), processing (\$1.50/chute entry), implant (\$8.44/implant), loan interest (at 20% equity and 5% interest per year), beef checkoff fees (\$2/animal), TCFA dues (\$0.007/animal/d), and insurance fees (\$0.009/animal/d)

[5]Total Expenses include cattle cost, feed costs, and miscellaneous costs

[6]Total Expenses w/ Freight include cattle cost, feed costs, miscellaneous costs, and freight (\$8/animal)

Table 5.5. Calculated revenue for cattle producers of implanted (REV) or non-implanted (CON) Angus × Charolais steers serially marketed at various end points [1, 2]

	Item	n	Shrunk BW, kg	Hot Carcass Weight, kg	Live Value, $/animal	In the Beef, $/carcass	Quality Adj, $/cwt	Yield Adj, $/cwt	Weight Adj, $/cwt	Grid Value[3], $/cwt	Grid Value, $/carcass
TRT[1]	CON	40	541	356	1385.00	1414.73	(8.95)	(3.04)	(9.53)	181.43	1435.15
	REV	40	572	379	1474.65	1507.6	(11.54)	(1.50)	(10.60)	159.16	1339.48
	SEM	-	5.57	4.83	15.42	19.38	0.97	0.75	1.26	2.03	19.40
DOF	0	8	271[h]	159[g]	692.56[h]	641.56[g]	(30.19)[c]	3.26[a]	(30.66)[c]	135.28[d]	479.08[h]
	42	8	362[g]	211[f]	940.53[g]	842.58[f]	(26.92)[c]	3.27[a]	(25.15)[c]	144.07[d]	673.41[g]
	84	8	420[f]	291[e]	1095.92[f]	1154.64[e]	(18.78)[b]	2.25[a]	(6.46)[a]	169.88[c]	1077.24[f]
	126	8	494[e]	320[e]	1271.23[e]	1271.48[e]	(13.74)[b]	1.05[a]	(3.90)[a]	176.26[bc]	1221.95[e]
	168	8	559[d]	371[d]	1443.06[d]	1471.09[d]	(4.09)[a]	1.62[a]	(0.35)[a]	190.06[a]	1533.69[d]
	210	8	635[c]	429[c]	1635.60[c]	1698.66[c]	(2.41)[a]	(0.87)[ab]	(3.19)[a]	186.42[ab]	1727.37[bc]
	252	8	635[c]	419[c]	1640.33[c]	1670.55[c]	(1.46)[a]	(5.37)[bc]	(0.44)[a]	185.60[ab]	1684.39[c]
	294	8	689[b]	469[b]	1727.95[c]	1863.60[b]	(5.28)[a]	(10.92)[d]	(6.73)[a]	169.94[c]	1722.91[bc]
	336	8	716[b]	477[b]	1827.84[b]	1889.10[b]	0.28[a]	(7.49)[cd]	(7.54)[a]	178.12[abc]	1830.40[ab]
	378	8	785[a]	531[a]	2023.20[a]	2108.39[a]	0.18[a]	(9.52)[cd]	(16.24)[b]	167.31[c]	1922.71[a]
	SEM	-	12.58	10.92	34.90	43.85	2.20	1.90	2.96	4.65	43.90
P - value	TRT× DOF	-	0.65	0.72	0.61	0.73	0.47	0.26	0.73	0.89	0.38
	TRT	-	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**0.06**	**0.10**	0.53	**<0.01**	**<0.01**
	DOF	-	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
	Lin	-	<0.01	0.01	<0.01	<0.01	<0.01	**<0.01**	<0.01	<0.01	<0.01
	Quad	-	**<0.01**	**0.01**	**<0.01**	**<0.01**	**<0.01**	0.21	**<0.01**	**<0.01**	**<0.01**

[a,b,c,d,e,f,g,h,i] Means in a column with differing superscripts are different

[1]Revalor-XS, Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS 200 mg trenbolone acetate and 40 mg estradiol 17-beta in a proprietary timed release coating) combination implant administered on 0 and 190 d; CON = negative control

[3]Grid value includes a $20.16/cwt premium for NHTC cattle

Table 5.6. Calculated net return for cattle producers of implanted (REV) or non-implanted (CON) Angus × Charolais steers serially marketed at various end points [1, 2]

	Item	n	Shrunk BW, kg	Hot Carcass Weight, kg	Live Basis	In the Beef Basis w/ Freight	Grid Basis w/ Freight
TRT[1]	CON	40	541	356	(218.33)	(196.58)	(176.17)
	REV	40	572	379	(107.36)	(82.41)	(250.52)
	SEM	–	5.57	4.83	12.98	17.72	18.73
DOF	0	8	271[h]	159[g]	(302.32)[d]	(361.41)[b]	(523.80)[d]
	42	8	362[g]	211[f]	(199.94)[c]	(305.86)[b]	(475.06)[d]
	84	8	420[f]	291[e]	(171.05)[bc]	(120.33)[b]	(197.73)[bc]
	126	8	494[e]	320[e]	(129.55)[abc]	(137.42)[a]	(186.83)[bc]
	168	8	559[d]	371[d]	(101.54)[ab]	(81.44)[a]	(18.92)[a]
	210	8	635[c]	429[c]	(87.33)[a]	(32.18)[a]	(3.56)[a]
	252	8	635[c]	419[c]	(131.02)[abc]	(108.85)[a]	(94.96)[ab]
	294	8	689[b]	469[b]	(174.47)[bc]	(46.81)[a]	(187.52)[bc]
	336	8	716[b]	477[b]	(198.91)[c]	(145.69)[a]	(204.34)[bc]
	378	8	785[a]	531[a]	(132.28)[abc]	(54.97)[a]	(240.77)[c]
	SEM	–	12.58	10.92	30.04	40.13	42.38
P - value	TRT× DOF	–	0.65	0.72	0.17	0.44	0.14
	TRT	–	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**0.01**
	DOF	–	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
	Lin	–	<0.01	0.01	<0.01	<0.01	<0.01
	Quad	–	**<0.01**	**0.01**	**<0.01**	**<0.01**	**<0.01**

[a,b,c,d,e,f,g,h] Means in a column with differing superscripts are different

[1]Revalor-XS, Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS 200 mg trenbolone acetate and 40 mg estradiol 17-beta in a proprietary timed release coating) combination implant administered on 0 and 190 d; CON = negative control

Table 5.7. Calculated value for beef processors of implanted (REV) or non-implanted (CON) Angus × Charolais steers serially marketed at various end points [1, 2]

	Item	n	Hot Carcass Weight, kg	**Expense** Grid Value, $/carcass	**Revenue** Non-carcass drop value, $/carcass	Boxed Value[3], $/carcass	Total Revenue	**Net** Return[4], $/carcass	Return w/ Freight[5], $/carcass
TRT[1]	CON	40	356	1435.15	310.45	1889.64	2200.09	574.94	566.94
	REV	40	379	1339.48	321.28	1796.17	2117.45	587.97	579.97
	SEM	–	4.83	19.40	3.44	20.74	21.43	20.03	20.04
DOF	0	8	159^{g}	479.08^{h}	200.86^{g}	858.55^{h}	1059.41^{i}	390.33^{d}	382.33^{d}
	42	8	211^{f}	673.41^{g}	247.12^{f}	1100.92^{g}	1348.04^{h}	484.63^{cd}	476.63^{cd}
	84	8	291^{e}	1077.24^{f}	266.17^{f}	1383.35^{f}	1649.52^{g}	382.28^{d}	374.28^{d}
	126	8	320^{e}	1221.95^{e}	294.66^{e}	1608.19^{e}	1902.85^{f}	490.91^{cd}	482.91^{cd}
	168	8	371^{d}	1533.69^{d}	317.00^{d}	1856.88^{d}	2173.89^{e}	450.20^{cd}	442.20^{cd}
	210	8	429^{c}	1727.37^{bc}	336.09^{cd}	2132.90^{c}	2468.99^{d}	551.62^{c}	543.62^{c}
	252	8	419^{c}	1684.39^{c}	337.77^{cd}	2108.41^{c}	2446.18^{d}	571.79^{c}	563.79^{c}
	294	8	469^{b}	1722.91^{bc}	354.33^{c}	2274.73^{b}	2629.06^{c}	716.15^{b}	708.15^{b}
	336	8	477^{b}	1830.40^{ab}	384.28^{b}	2394.84^{b}	2779.12^{b}	758.72^{b}	750.72^{b}
	378	8	531^{a}	1922.71^{a}	420.37^{a}	2710.25^{a}	3130.62^{a}	1017.91^{a}	1009.91^{a}
	SEM	–	10.92	43.90	7.79	46.94	48.5	45.34	45.34
P - value	TRT× DOF	–	0.72	0.38	0.21	0.22	0.29	0.95	0.95
	TRT	–	**<0.01**	**<0.01**	**0.03**	**<0.01**	**0.01**	0.65	0.65
	DOF	–	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**
	Lin	–	0.01	<0.01	**<0.01**	<0.01	<0.01	<0.01	<0.01
	Quad	–	**0.01**	**<0.01**	0.12	**<0.01**	**<0.01**	**<0.01**	**<0.01**

[a,b,c,d,e,f,g,h,i] Means in a row with differing superscripts are different

[1]Revalor-XS, Merck Animal Health, Madison, NJ

[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol 17-beta in a proprietary timed release coating) combination implant administered on 0 and 190 d; CON = negative control

[3]Boxed Value is the product of $/side × 2

[4]Return is calculated by difference in (Boxed Value + Drop Credit) – {Overhead costs ($190/carcass) + Grid Value}

[5]Return w/ Freight is calculated as difference in (Boxed Value + Drop Credit) – {Overhead costs ($190/carcass) + Grid Value + Freight ($8/animal)}

Table 5.8. Calculated NHTC premiums required for CON steers to breakeven

	Item	n	Live, \$/cwt	In the Beef w/ Freight, \$/cwt	Grid w/ Freight, \$/cwt
TRT	CON	40	25.81	34.13	55.65
	SEM	-	1.24	2.45	3.17
DOF	0	4	35.88[a]	103.42[a]	160.97[a]
	42	4	29.15[ab]	66.86[b]	115.67[b]
	84	4	16.25[bc]	22.68[c]	45.66[c]
	126	4	13.78[c]	19.08[cd]	35.62[cd]
	168	4	10.16[c]	10.72[cd]	13.56[e]
	210	4	8.82[c]	3.95[d]	10.46[e]
	252	4	10.71[c]	12.61[cd]	19.86[de]
	294	4	14.29[c]	5.31[d]	28.26[cde]
	336	4	16.56[bc]	14.69[cd]	29.43[cde]
	378	4	10.52[c]	5.02[d]	30.65[cde]
	SEM	-	4.72	6.21	7.41
P-value	DOF	-	**<0.01**	**<0.01**	**<0.01**
	Lin	-	<0.01	<0.01	<0.01
	Quad	-	**<0.01**	**<0.01**	**<0.01**

[a,b,c,d,e] Means in a row with differing superscripts are different

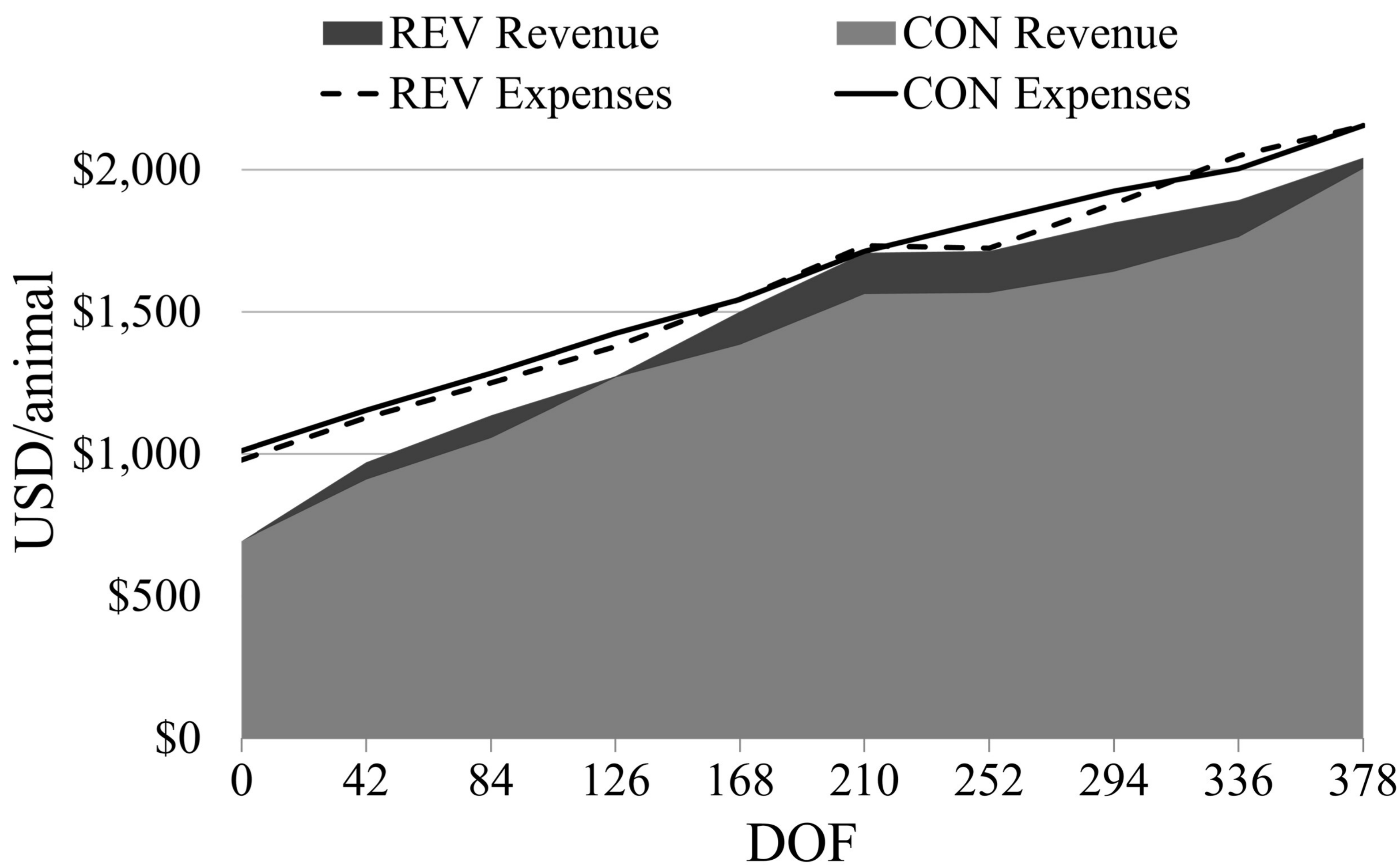


Figure 5.1. Profitability of implanted (REV) or non-implanted (CON) Charolais × Angus steers serially marketed on a live basis at various end points

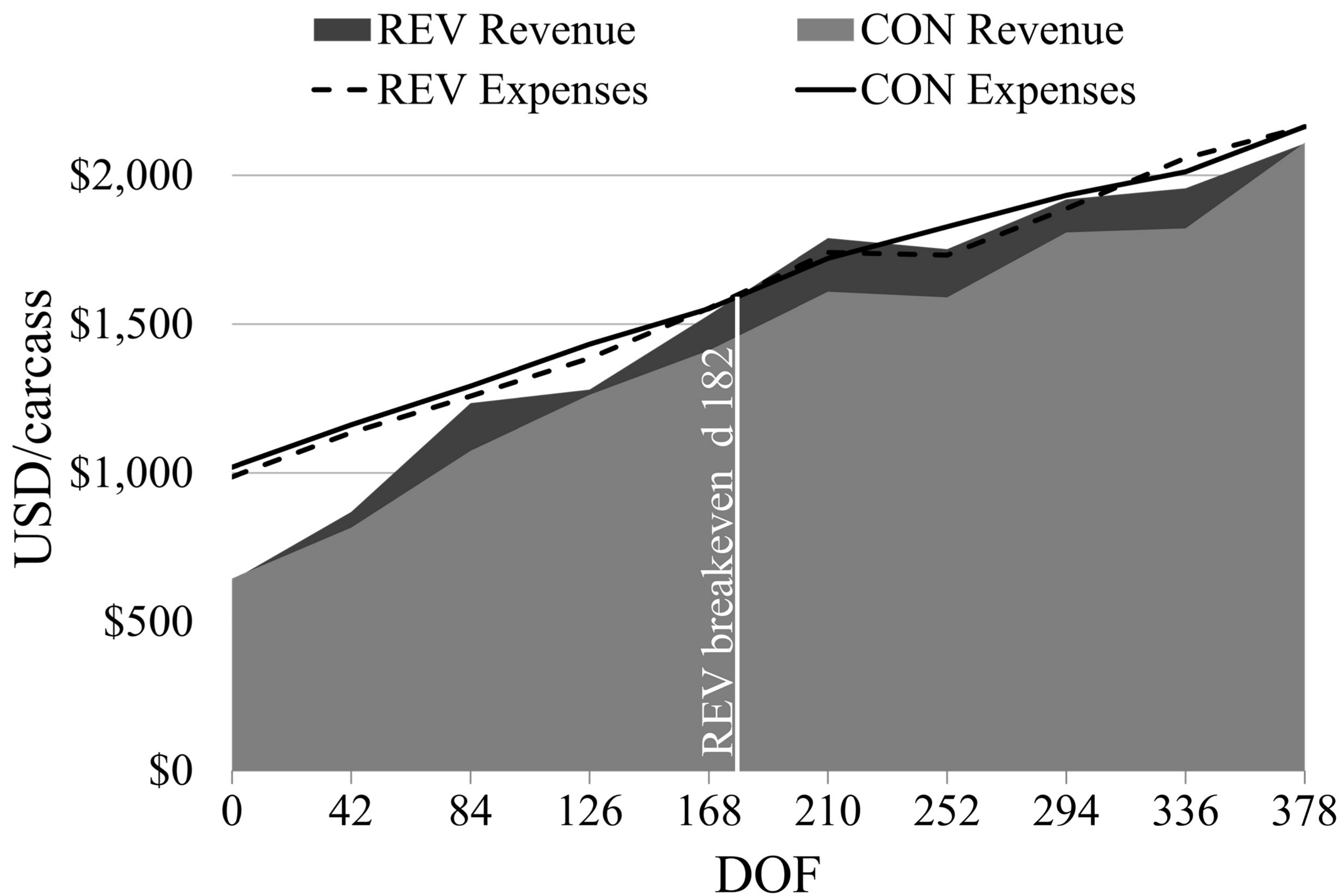


Figure 5.2. Profitability of implanted (REV) or non-implanted (CON) Charolais × Angus steers serially marketed on an in the beef basis at various end points

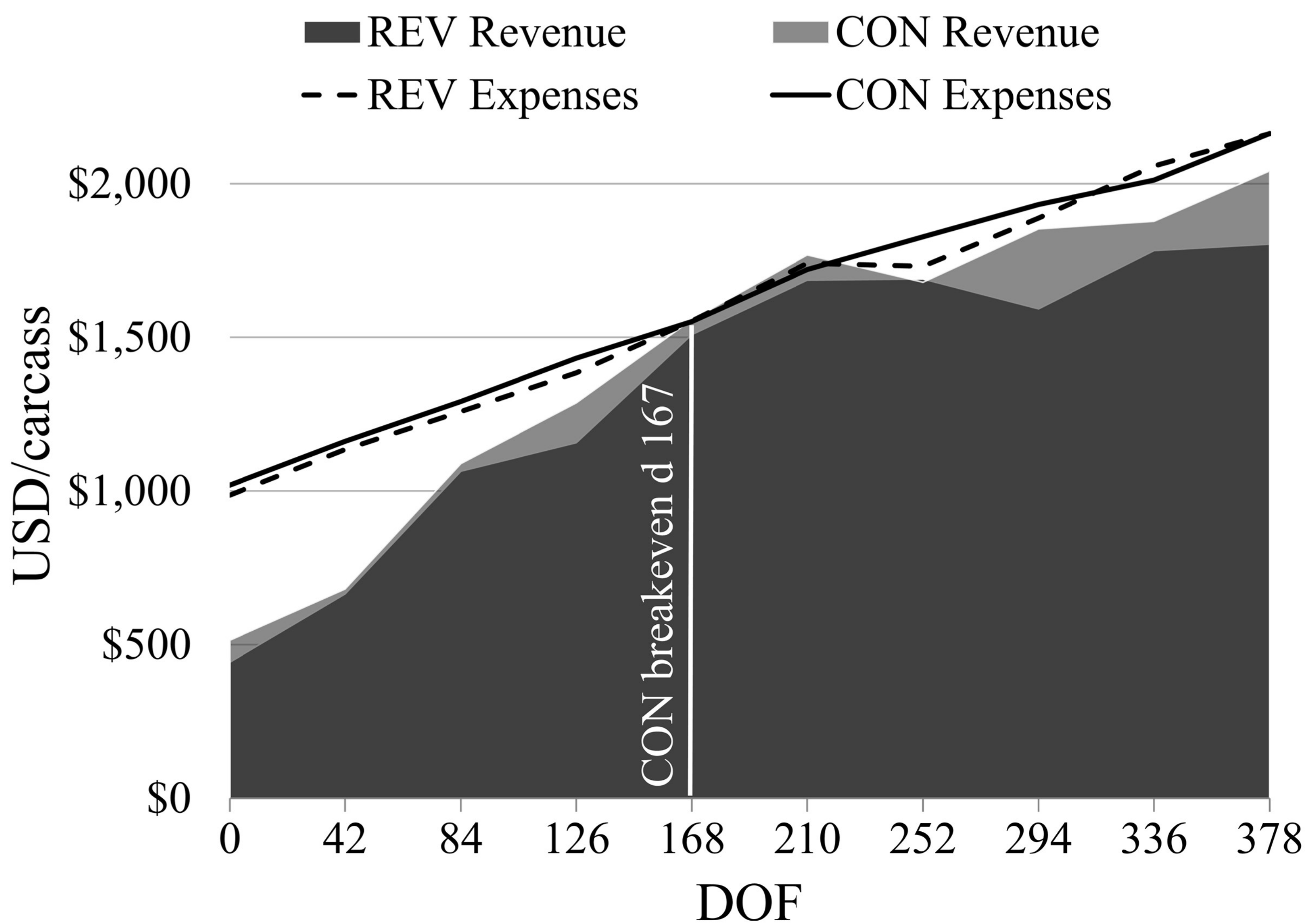


Figure 5.3. Profitability of implanted (REV) or non-implanted (CON) Charolais × Angus steers serially marketed on a grid basis at various end points

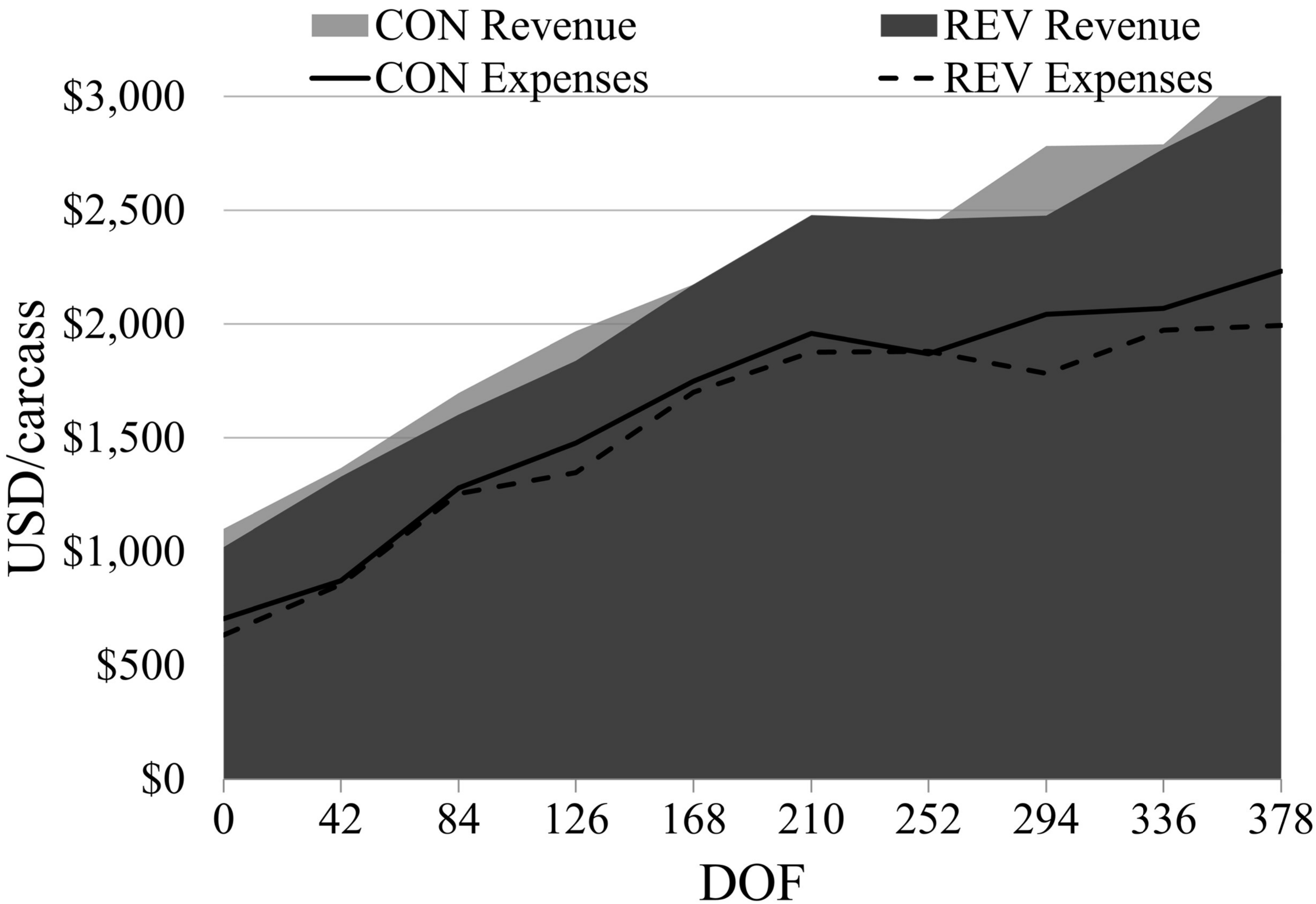
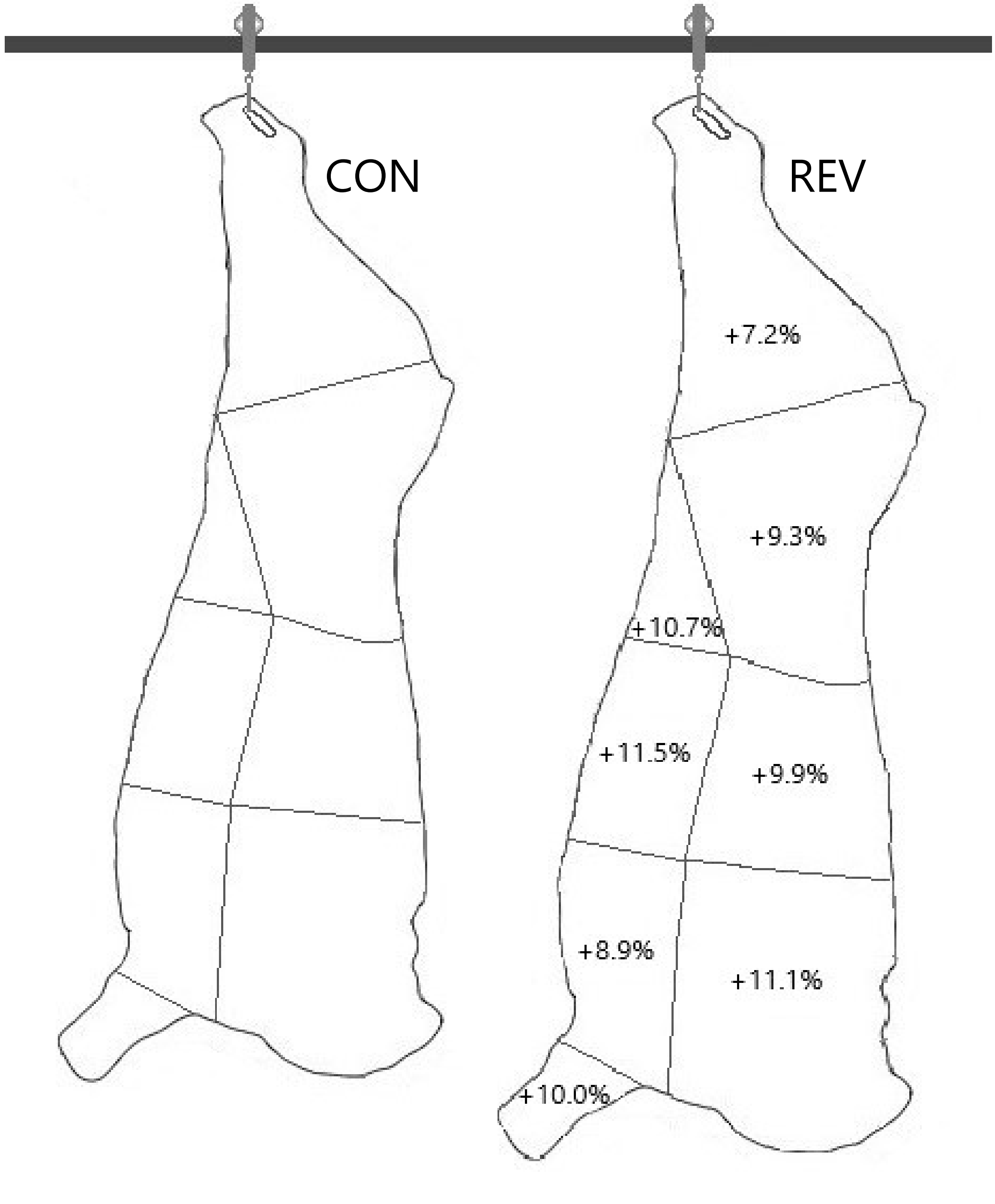
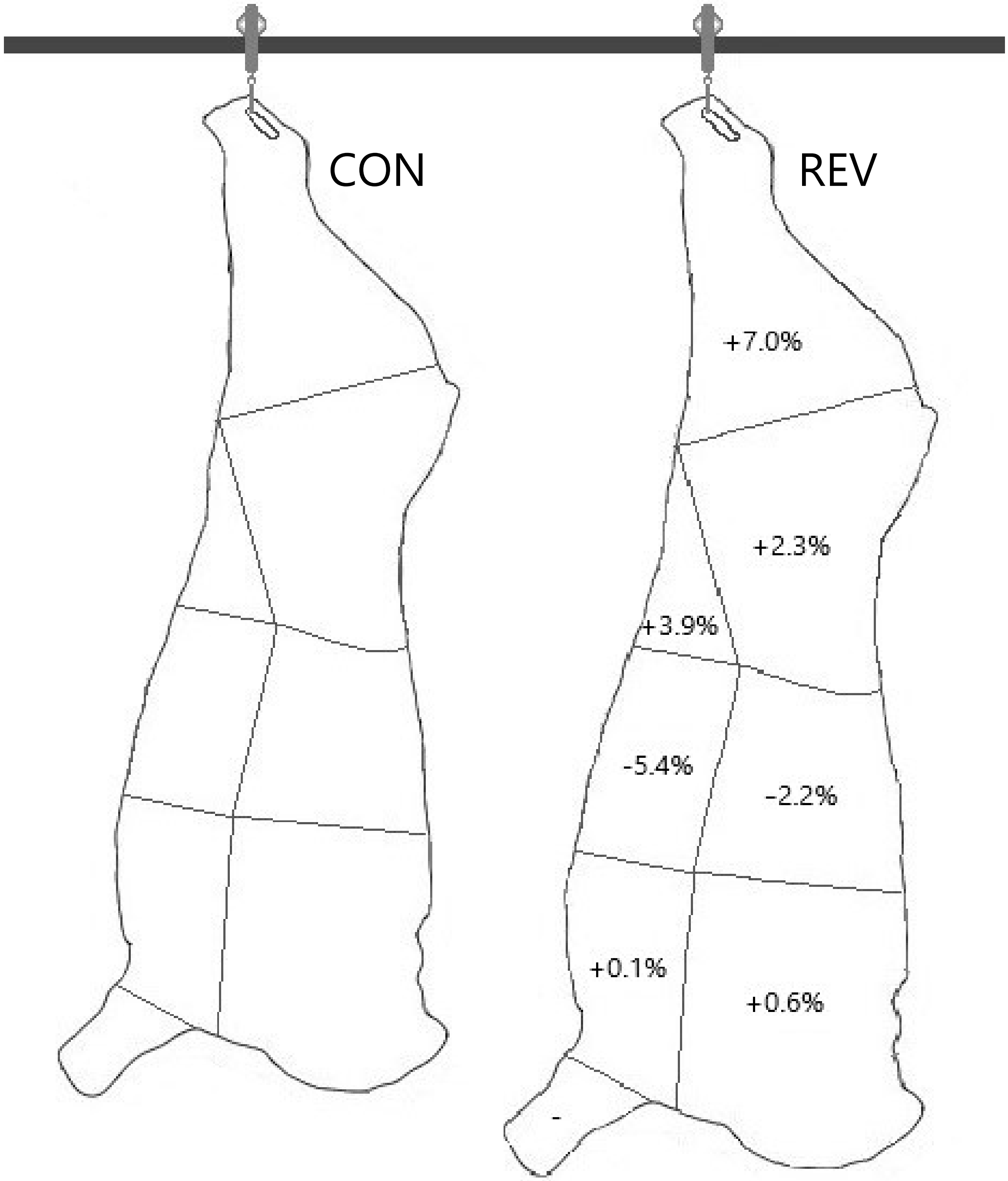


Figure 5.4. Net returns of implanted (REV) or non-implanted (CON) Charolais × Angus steers serially marketed at various end points for beef processors

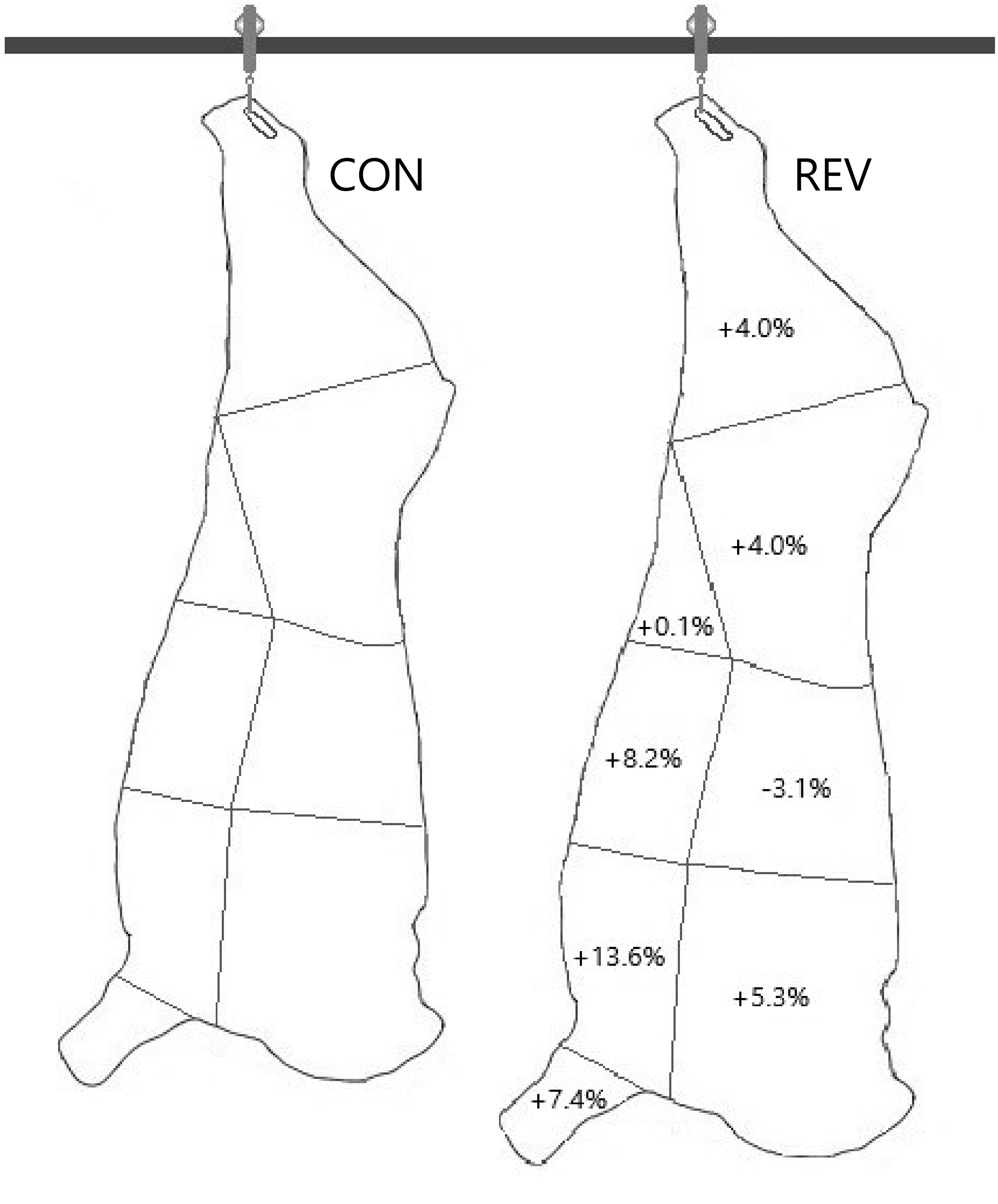
APPENDICES



Appendix A: Percentage change of primal lean weights from non-implanted (CON) to implanted (REV) Charolais × Angus steers serially harvested at various market end points

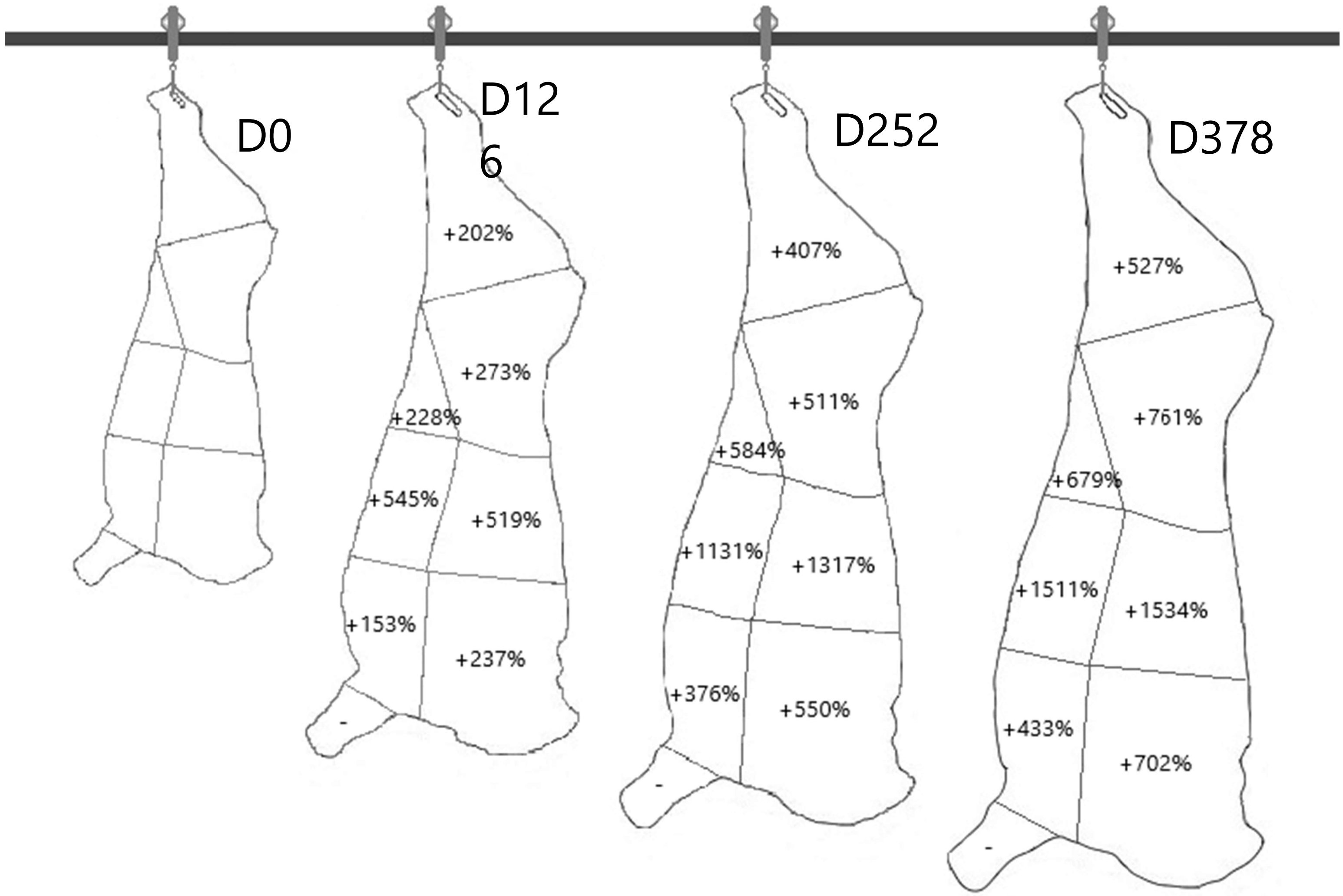


Appendix B: Percentage change of primal fat weights from non-implanted (CON) to implanted (REV) Charolais × Angus steers serially harvested at various market end points

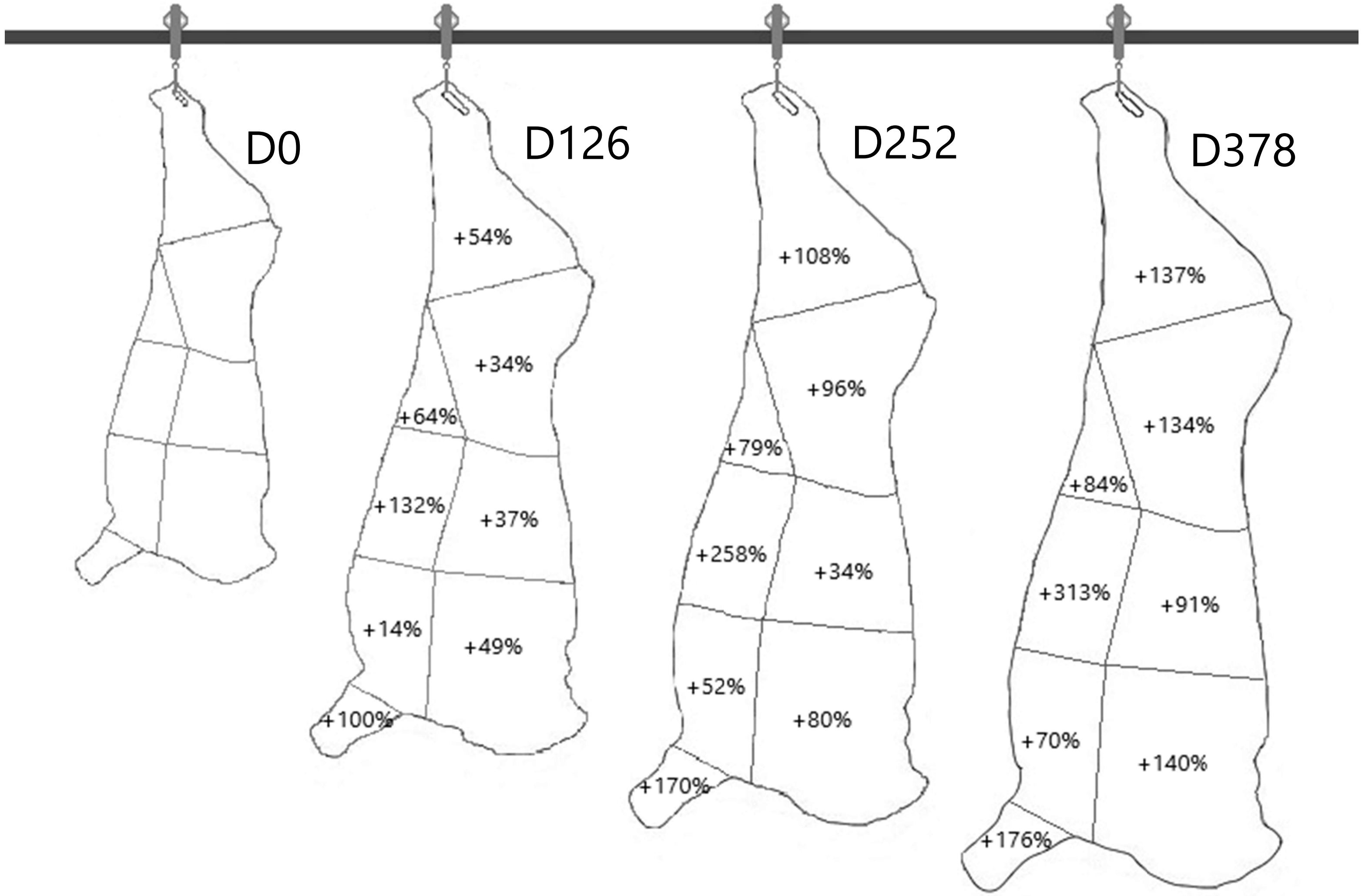


Appendix C: Percentage change of primal bone weights from non-implanted (CON) to implanted (REV) Charolais × Angus steers serially harvested at various market end points

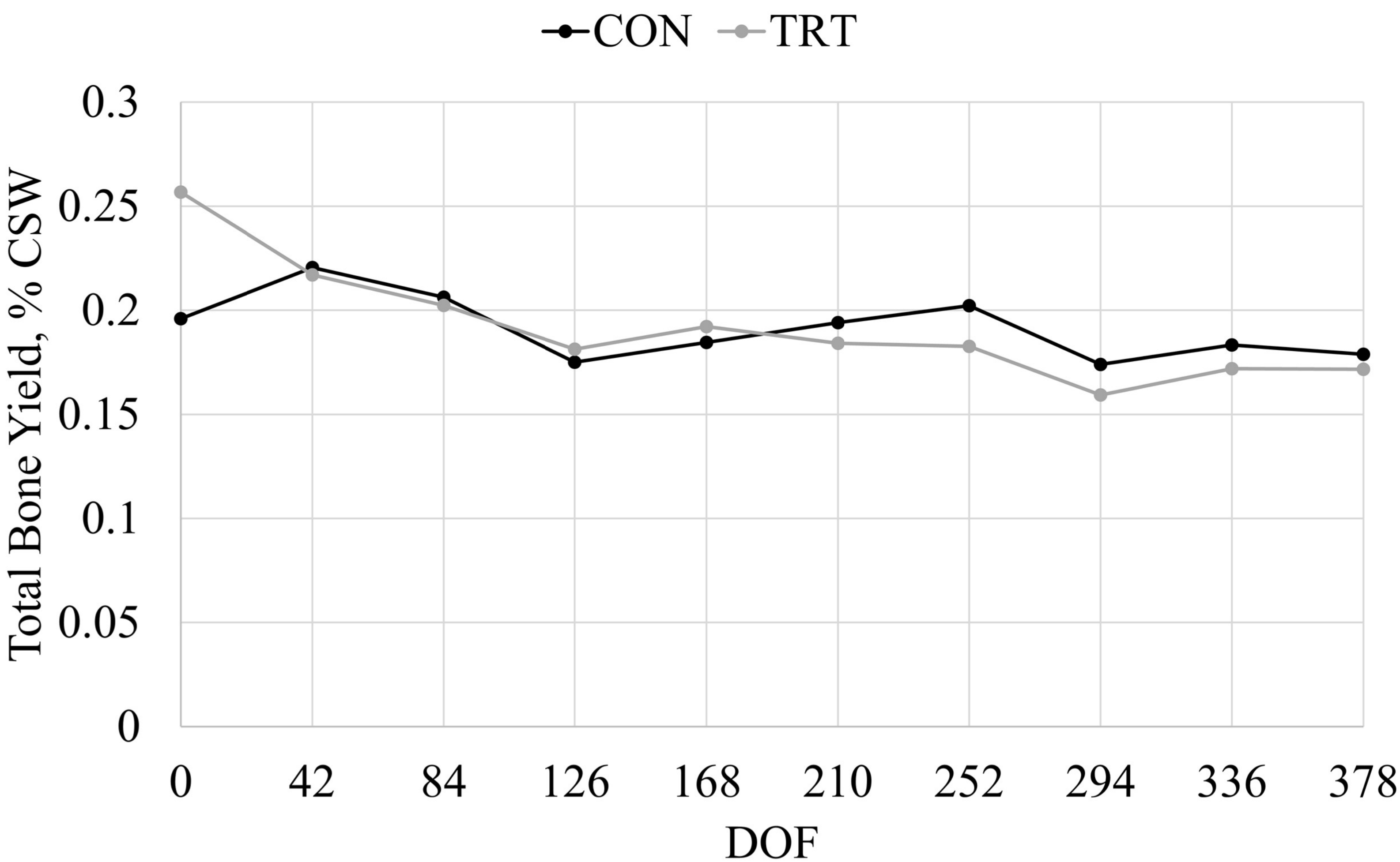
Appendix D: Percentage change of primal lean weights of Charolais × Angus steers serially harvested at marketing endpoints from d 0 to d 126, 252 and 378



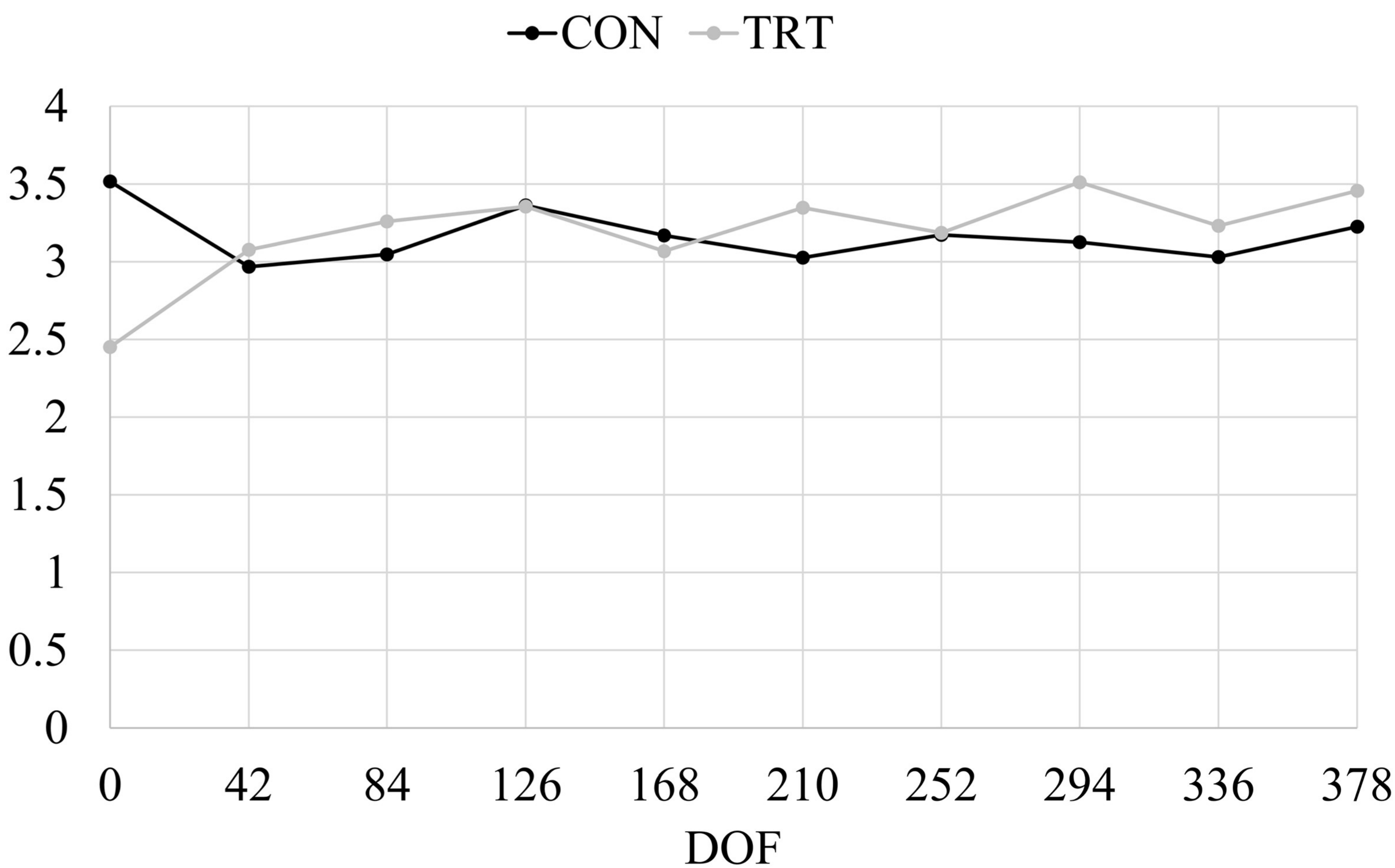
Appendix E: Percentage change of primal fat weights of Charolais × Angus steers serially harvested at marketing endpoints from d 0 to d 126, 252 and 378



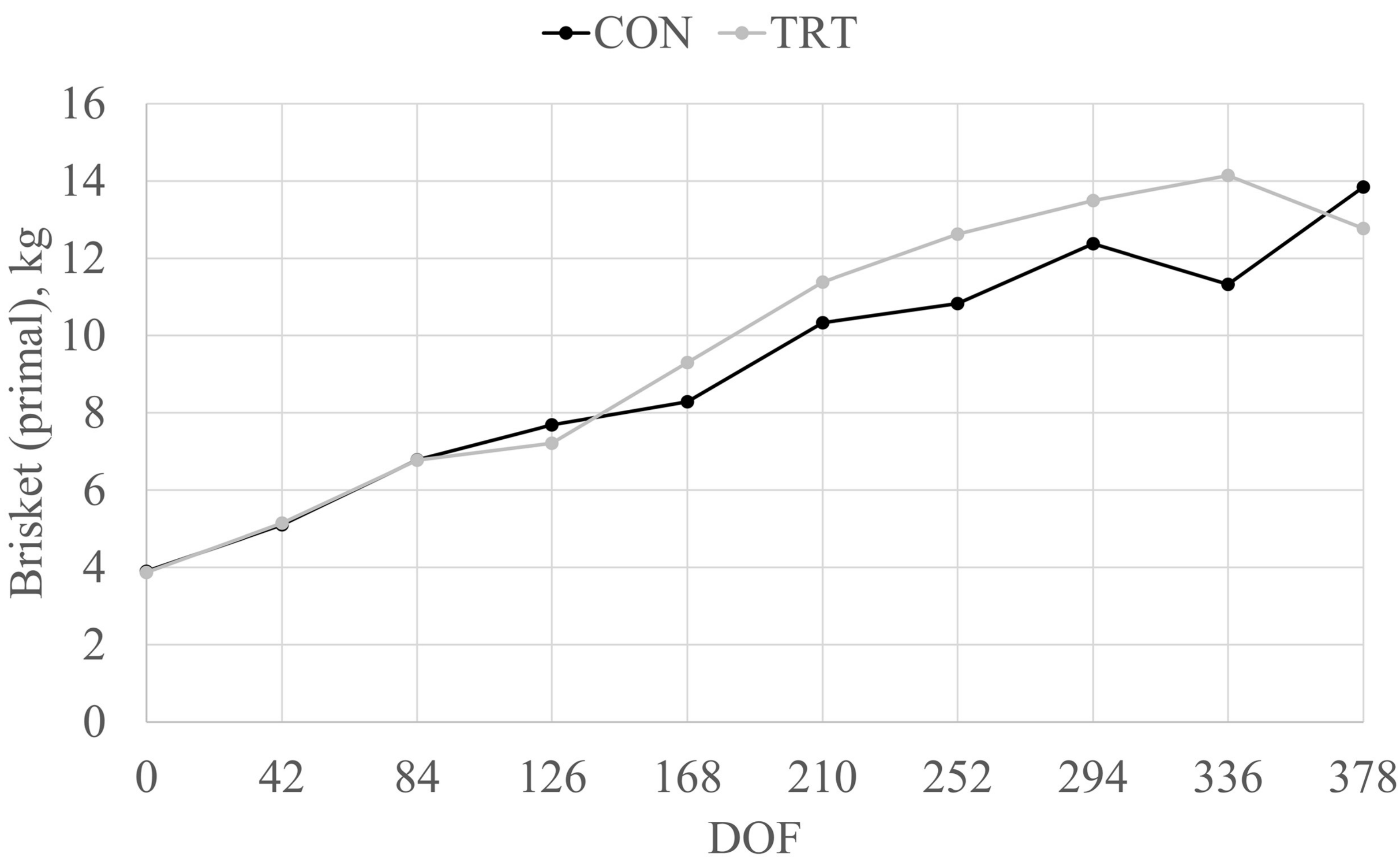
Appendix F: Percentage change of primal bone weights of Charolais × Angus steers serially harvested at marketing endpoints from d 0 to d 126, 252 and 378



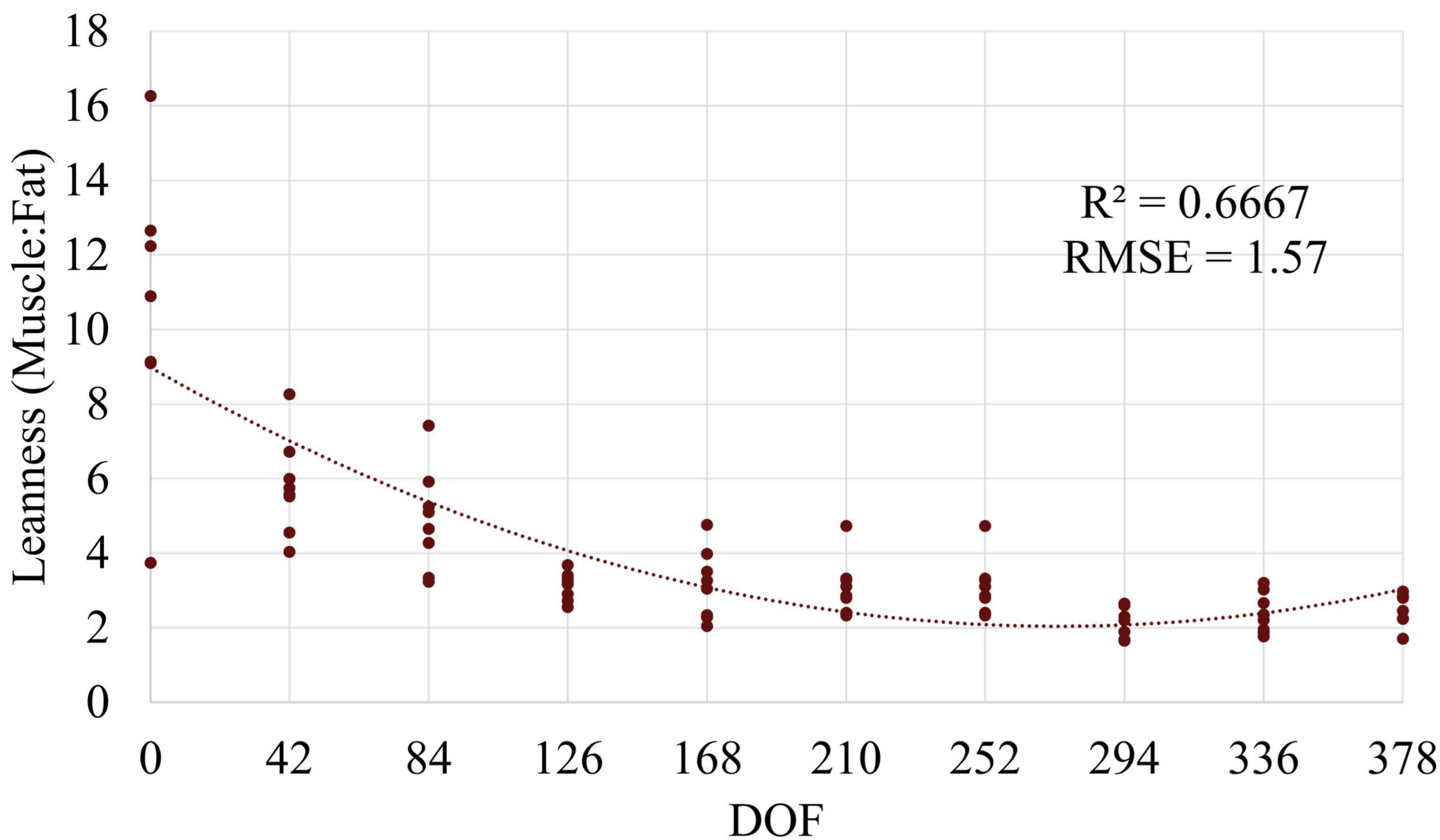
Appendix G: Total bone yield as % CSW for non-implanted (CON) or implanted (REV) Charolais × Angus steers across varying days on feed



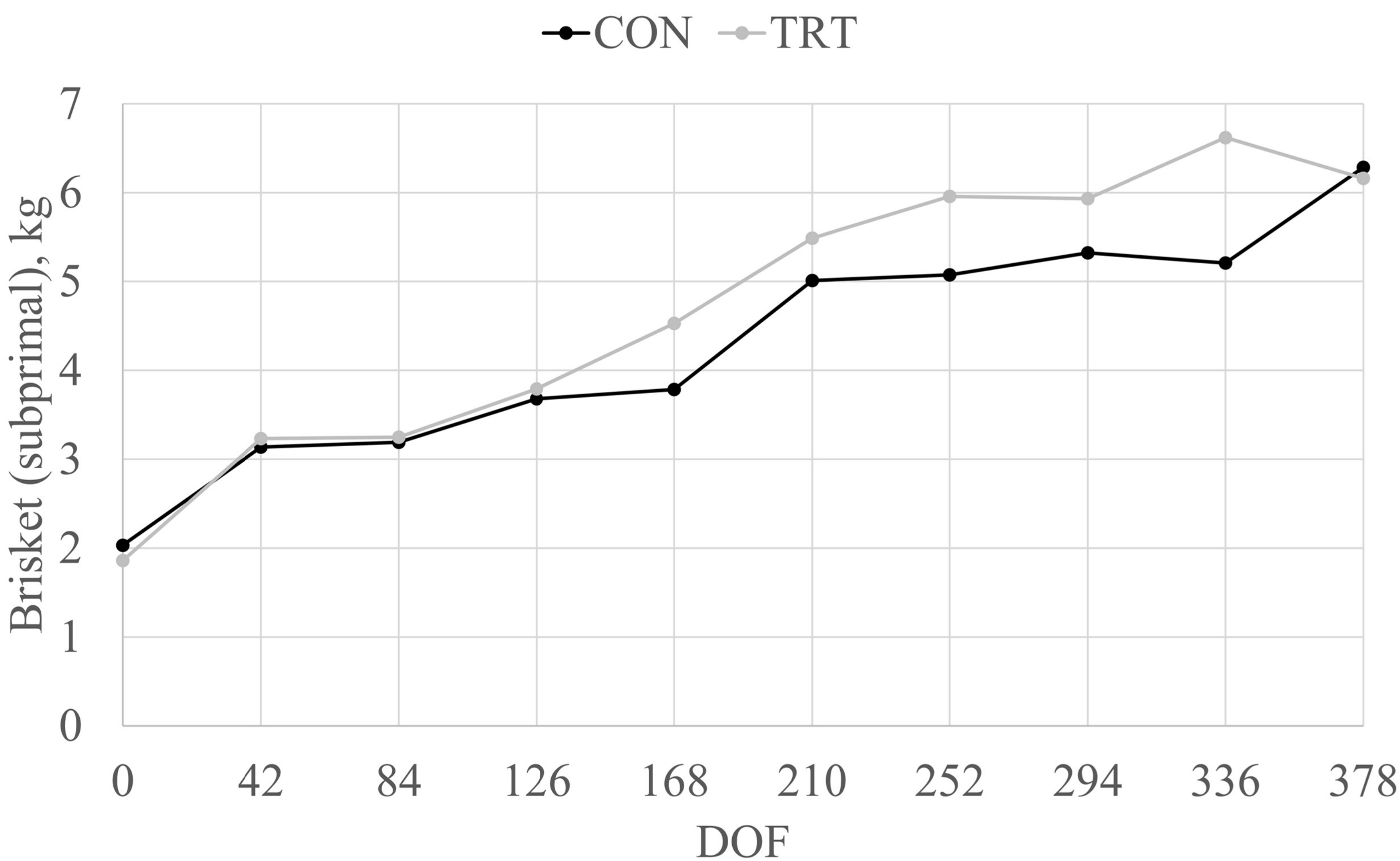
Appendix H: Muscling for non-implanted (CON) or implanted (REV) Charolais × Angus steers across varying days on feed



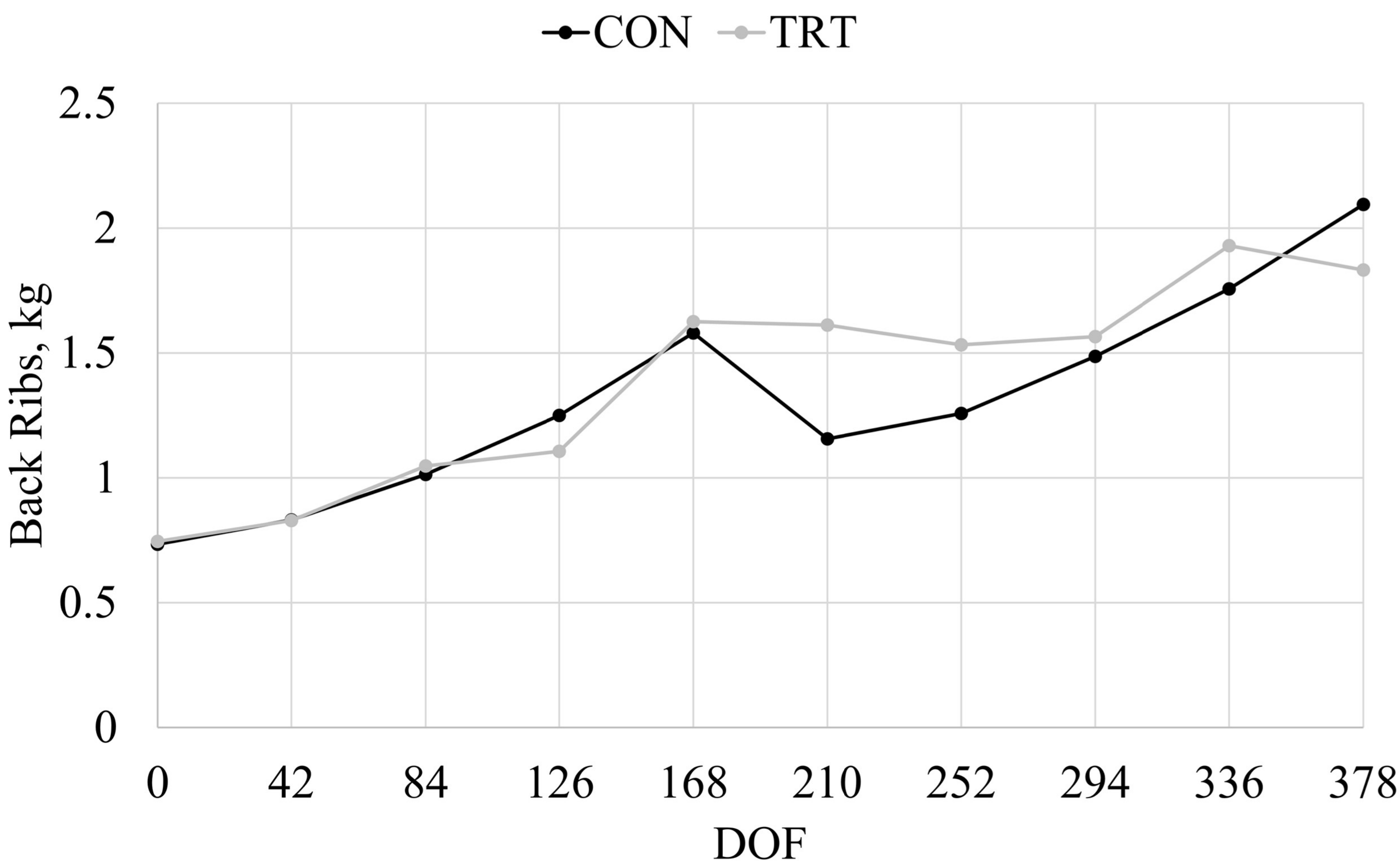
Appendix I: Brisket primal absolute weight for non-implanted (CON) or implanted (REV) Charolais × Angus steers across varying days on feed



Appendix J: Prediction equation, R^2, and RMSE for leanness across varying days on feed



Appendix K: Brisket subprimal absolute weight for non-implanted (CON) or implanted (REV) Charolais × Angus steers across varying days on feed



Appendix L: Back ribs absolute weight for non-implanted (CON) or implanted (REV) Charolais × Angus steers across varying days on feed

Appendix M: Prediction equations for the determination of brisket, chuck, rib, and plate subprimals as % CSW of non-implanted (CON) or implanted (REV) Charolais × Angus steers using DOF as the independent variable

Item	Quadratic	Power	Adjusted R^2	RMSE
Brisket, % CSW	-	-	-	-
Arm Roast, % CSW	$-0.000000003X^2-0.00000818X+0.01929$	-	0.32	0.002
Flat Iron, % CSW	$-0.00000002X^2+0.00000466X+0.01362$	-	0.17	0.001
Petite Tender, % CSW	-	$0.00305065e^{-0.00094315x}$		
Chuck Eye Roll, % CSW	$0.00000002X^2-0.00002822X+0.03984$	-	0.33	0.004
Mock Tender, % CSW	$-0.00000001X^2-0.00000606X+0.00985$	-	0.65	0.001
Pectoral Meat, % CSW	$0.00000008X^2-0.00004243X+0.00886$	-	0.68	0.001
Ribeye Roll, % CSW	$0.000000004X^2-0.00000501X+0.03235$	-	0.005	0.003
Back Ribs, % CSW	$0.00000002X^2-0.00001283X+0.00936$	-	0.14	0.001
Short Ribs, % CSW	$-0.00000004+0.00001461+0.00927$	-	0.04	0.002
Rib Blade Meat, % CSW	$-0.00000002X^2+0.00000265X+0.00695$	-	0.14	0.001
Inside Skirt, % CSW	$0.000000006X^2-0.00000651X+0.00888$	-	0.25	0.001
Outside Skirt, % CSW				
CON	$0.00000001X^2-0.00000700X+0.00460$	-	0.10	0.001
REV	$0.000000009X^2-0.00000621+0.00504$	-	0.23	0.001

[1]Merck Animal Health, Madison, NJ

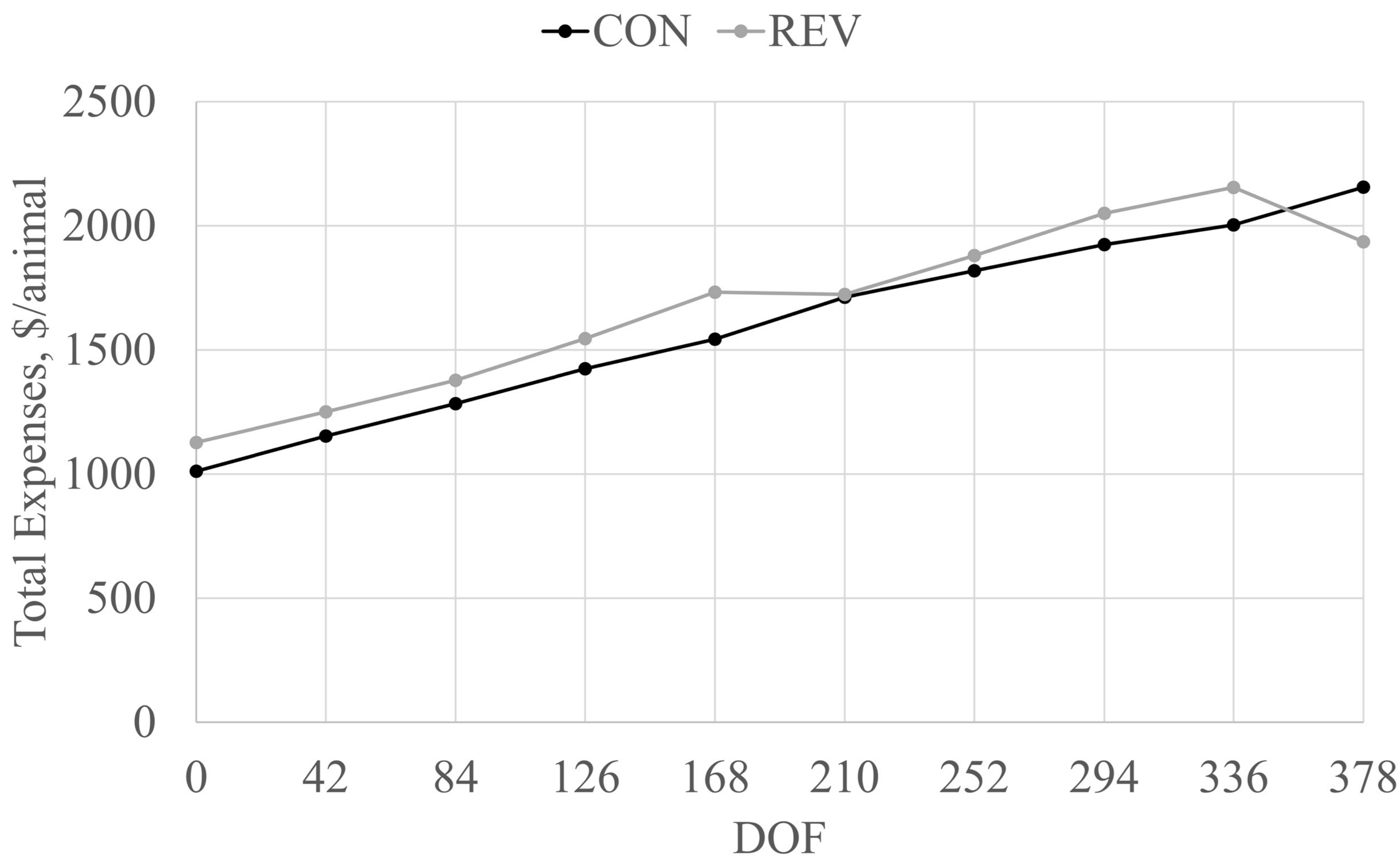
[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control

Appendix N: Prediction equations for the determination of loin, flank, and round subprimals as %CSW of non-implanted (CON) or implanted (REV) Charolais × Angus steers using DOF as the independent variable

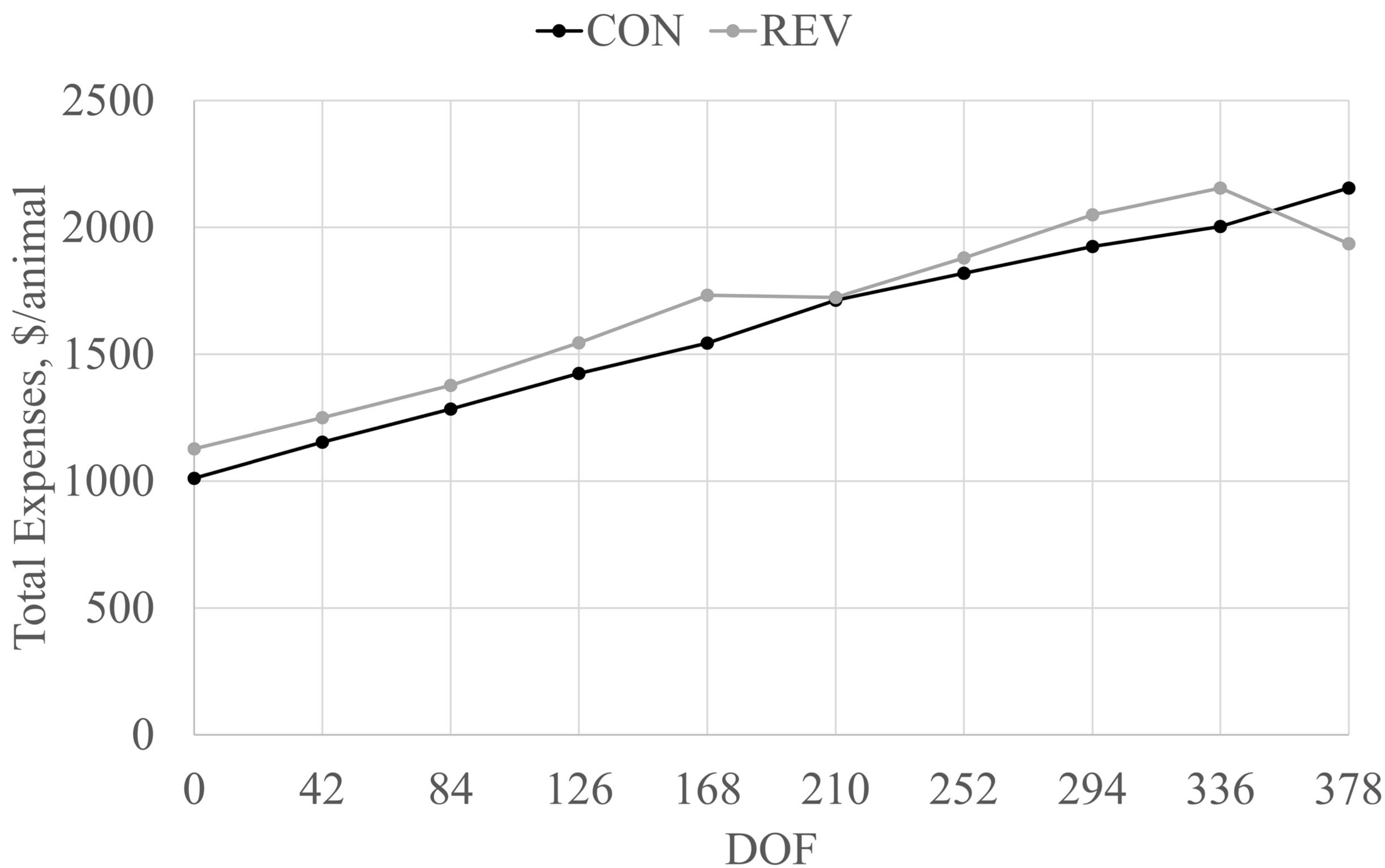
Item	Quadratic	Power	Adjusted R^2	RMSE
Striploin, % CSW	$00000003X^2-0.00003816X+0.03247$	-	0.55	0.003
Tenderloin, % CSW	$0.00000004X^2-0.00002390X+0.01606$	-	0.53	0.001
Top Sirloin Butt, % CSW	$0.00000004X^2-0.00003021X+0.02652$	-	0.54	0.002
Top Sirloin Butt Cap, % CSW	-	-	-	-
Bottom Sirloin Ball Tip, % CSW	-	-	-	-
Bottom Sirloin Tri-Tip, % CSW	$0.000000006X^2-0.00000625X+0.00807$	-	0.23	0.001
Hanging Tender, % CSW	$0.00000001X^2-0.00000776X+0.00392$	-	0.16	0.001
Bottom Sirloin Flap, % CSW	-	-	-	-
Flank Steak, % CSW	$0.00000003X^2-0.00001430X+0.00705$	-	0.31	0.01
Elephant Ear, % CSW	$-0.00000007X^2+0.00003565X+0.00873$	-	0.16	0.003
Top Round, % CSW	$0.00000016X^2-0.00011636X+0.06713$	-	0.74	0.004
Sirloin Tip, % CSW	$0.00000008X^2-0.00006823X+0.04040$	-	0.64	0.004
Bottom Round, % CSW	$0.00000011X^2-0.00006970X+0.03957$	-	0.60	0.003
Eye Of Round, % CSW	$0.00000003X^2-0.0002203X+0.01645$	-	0.50	0.002
Heel Meat, % CSW	-	$0.01719763e^{-0.00130454x}$		

[1]Merck Animal Health, Madison, NJ

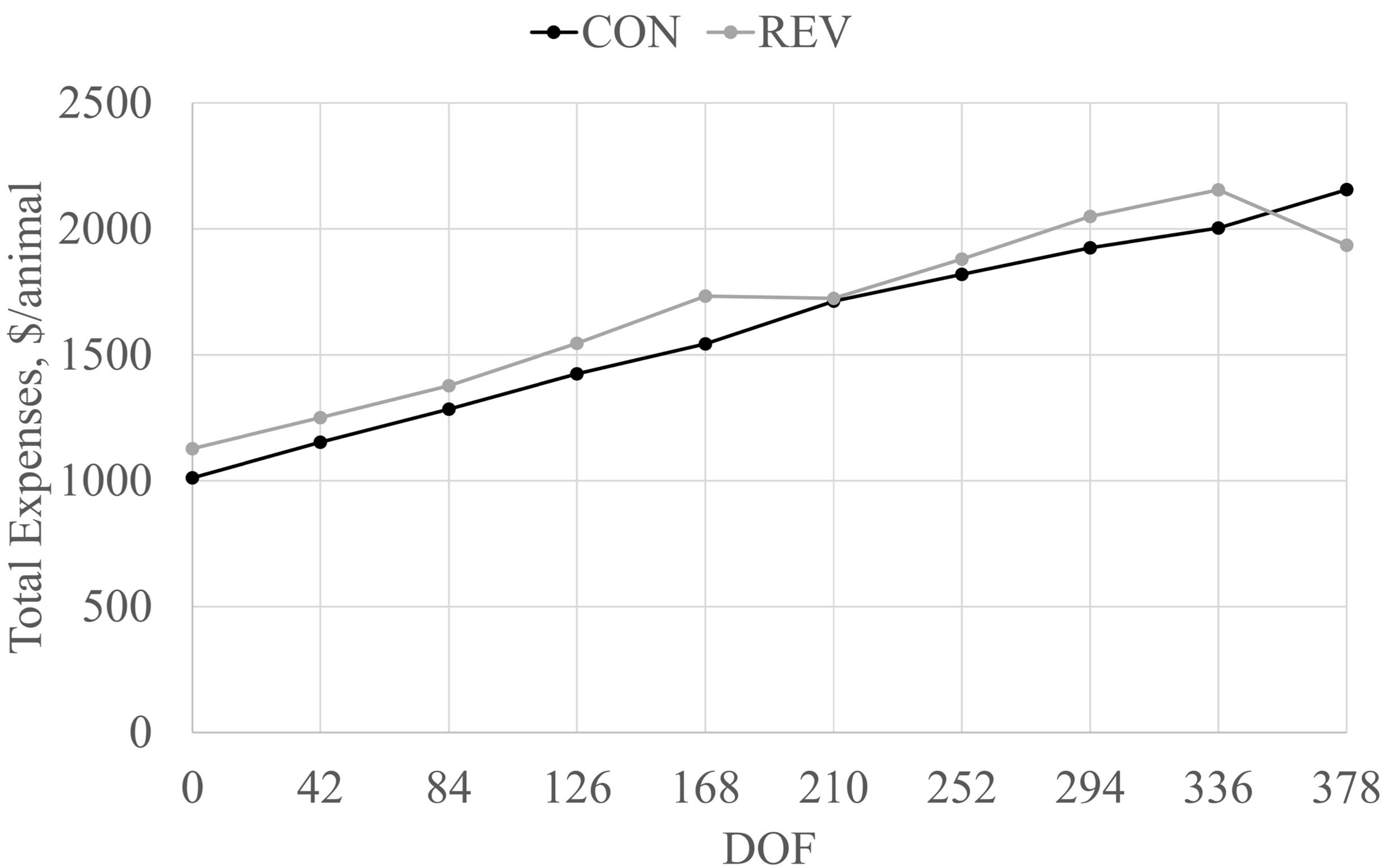
[2]REV = Revalor-XS (200 mg trenbolone acetate and 40 mg estradiol) combination implant administered on 0 and 190 d; CON = negative control



Appendix O: Interaction of feed costs of non-implanted (CON) or implanted (REV) Charolais × Angus steers across varying days on feed



Appendix P: Interaction of producer expenses without freight expenses of non-implanted (CON) or implanted (REV) Charolais × Angus steers across varying days on feed



Appendix Q: Interaction of producer expenses including freight expenses of non-implanted (CON) or implanted (REV) Charolais × Angus steers across varying days on feed