5-2012

Growth Promoting Implants and Nutrient Restriction Prior to Feeding: Effect on Carcass Composition, Carcass Quality, and Consumer Acceptability of Beef

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GROWTH PROMOTING IMPLANTS AND NUTRIENT RESTRICTION PRIOR TO FEEDING: EFFECT ON CARCASS COMPOSITION, CARCASS QUALITY, AND CONSUMER ACCEPTABILITY OF BEEF

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A thesis submitted in partial fulfillment

of the requirements for the degree of

Master of Science in Animal Science

By

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Morehead State University

Bachelor of Science in Agriculture, 2009

May 2012

University of Arkansas

ABSTRACT

Implant strategy and nutrient restriction prior to finishing may alter feedlot performance, as well as carcass characteristics and consumer acceptability of beef. The objectives of these studies were to determine the effect of prefinishing implant strategy and plane of nutrition on prefinishing and feedlot performance, carcass characteristics and quality, and consumer acceptability of beef. In 2 experiments, spring-born calves were weaned in the fall (Exp. 1, n =120; and Exp. 2, n = 96) and were either finished as calves (CALF-FED) or placed on a growing program with a target ADG of 0.45 kg/d (RSTR) or 0.91 kg/d (UNRSTR) before finishing. One-half of each backgrounding group received moderate potency hormonal implants with 200 mg progesterone and 20 mg estradiol benzoate (Synovex-S; Pfizer Animal Health, Madison, NJ) for steers or 200 mg testosterone propionate and 20 mg estradiol benzoate (Synovex-H; Pfizer Animal Health) for heifers before finishing (IMPL). At arrival to the feedyard all cattle were implanted with a moderate potency implant and were reimplanted following 100-d (CALF-FED) or 81-d on feed (UNRSTR and RSTR). Animal performance and carcass characteristics data were analyzed as a split plot design using the Mixed procedure of SAS. Treatment least-squares means were separated using predicted differences. Implantation prefinishing positively affected ($P < 0.01$) ADG in UNRSTR cattle in the feedlot in Exp. 1, and in all growth treatment groups ($P < 0.01$) in Exp. 2. Cattle in the UNRSTR treatment had greater ($P < 0.01$) HCW than CALF-FED or RSTR in both experiments, but there was no effect (= 0.38) of implant on HCW. Cattle fed as calves had a greater ($P = 0.02$) marbling score than yearlings in Exp. 1, but there were no differences ($P = 0.32$) in marbling scores across treatments in Exp. 2. In Exp 1, IMPL cattle tended ($P = 0.06$) to have a lower marbling score and had reduced ($P = 0.03$) percentage of cattle grading Choice; however, there was no effect ($P \geq 0.32$) of implant strategy on the percentage of cattle grading Choice or on marbling score. Cattle receiving an implant prefinishing had less ($P \leq 0.03$) initial and sustained tenderness than cattle that received a delayed implant in Exp 1 and 2.

Key Words: carcass quality, feed efficiency, implant, nutrient restriction, sensory

This thesis is approved for recommendation

to the Graduate Council.

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ACKNOWLEDGEMENTS

I would like to acknowledge and extend my appreciation to all of those whom this project and my graduate degree would not have been possible without; Dr. Paul Beck for your guidance, patience, and tutelage throughout my graduate program; Dr. Ryan Reuter for your mentorship and direction throughout my research; Dr. Jason Apple for helping to guide my way through the field of meat science and for extending your endless help in a subject foreign to me; and the late Dr. Brett Barham, whom will be dearly missed in the field of animal science and in the hearts of many. I would also like to acknowledge the Arkansas Beef Council for making this study possible by providing the funding necessary. Thank you to the crew at the Southwest Research and Extension Center – without you help, this project would not have been a success. And thank you to the Samuel Roberts Noble Foundation Agriculture Research Division – you saw something in me to take a chance on, funding my graduate education and providing me with an experience and education that could be surpassed by none. Thank you.

DEDICATION

My deepest appreciation goes out to numerous people who helped me succeed throughout my life and through the duration of my graduate school career. Thank you to each and every mentor that has crossed my path through my academic career that saw my potential to succeed and pushed me to achieve everything within my capabilities and more – you made me want to be the best that I can be. My deepest thank you, Dr. Beck and Dr. Reuter, for allowing me the opportunity to work closely with you, for educating me in the field of Animal Science and research, allowing me the opportunity to learn from your ways, and for remaining patient with me when I know your patience had long run out. Without your commitment and belief in me, I would not have made it to where I am today. Thank you to Kimberly – we made it through this together. Who knows where I would be without your encouragement, friendship, and much-needed support. Thank you, Benjamin. You helped me to see that I can do anything and nothing is beyond my limits if I believe it. Thank you to my entire family and friends for your undying love and support. But most of all thank you to my dad and mom, T.R. and Cindy Robinette, who have never once had a doubt in their minds about what I can achieve in life. You instilled in me discipline and work ethic, taught me anything worth having does not come easily, and encouraged my love of agriculture and the cattle business to take root and grow. For that, I am eternally grateful.

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CHAPTER I

INTRODUCTION

Although great strides have been made in improving the United States beef cattle industry over the past years, low USDA quality grades and the incidence of high USDA yield grades continue to loom as cattle producers' greatest areas of concern (Shook et al., 2008). Several aspects of cattle management can affect the quality of carcasses, including age entering the feedlot, implant strategy used, and plane of nutrition prior to finishing. Cattle that have been fed on a high plane of nutrition, or fed an energy-dense diet prior to entering the feedlot have been shown to be fatter when entering the finishing phase compared with cattle that have been nutritionally restricted (Baker et al., 1992). Some cattle go through a stocker phase of production where they are grown on pasture until they enter the feedlot and finish as yearlings, while others begin their finishing phase directly after weaning and are finished as calves (calf-feds; Griffin et al., 2007). Griffin et al. (2007) found that when comparing cattle of equal fat thickness, yearlings had fewer days on feed to produce a similar quality carcass, along with depositing intramuscular fat at a greater rate and having a greater rate of gain compared with calf-fed animals. Conversely, cattle fed as calves often result in greater yield grade carcasses, but in many instances the quality grade has been equal to, or greater than, cattle fed as yearlings (Smith and Lunt, 2007).

Anabolic implants were first used in cattle production systems in the 1950's to accelerate animal weights gains, improve carcass leanness, increase red meat yield, and improve feed efficiency. However, with the benefits of using steroidal implants come potential pitfalls, such as reduced tenderness, intramuscular fat, palatability, and flavor of beef, causing a less than desirable eating experience for the consumer (Roeber et al., 2000). Because there is limited evidence available on the interaction of implants, plane of nutrition, and backgrounding phase nutrition. Thus, the objectives of this thesis were to determine the effects of implant status and energy balance prefinishing on prefinishing and finishing phase performance, carcass quality and characteristics, and sensory panel evaluation.

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CHAPTER II

LITERATURE REVIEW

U.S. Cattle Industry

There are many challenges facing the beef industry today. Although beef production in the United States has improved in many ways, there are still obstacles for producers to continue to improve the efficiency of the industry. The rising cost of transportation, fuel, and grain prices, increasing value of land, incidence of drought, and animal activism are just a few challenges looming over the industry. Although the beef cattle industry represents the single largest segment of the American agriculture industry, the interest in farming and ranching of the younger generation is declining. As older producers retire or pass away, the younger generation is less inclined to take over a cattle operation, causing the number of producers in the nation to decline.

Along with the increase in grain prices, cattle prices are forecasted to continue to climb as well (Mark, 2010). The inventory of cattle across the United States is at a historically low level and herd sizes across the country are continuing to get smaller (Mintert et al., 2003). Though North America claims 30% of the world's cattle inventory, the U.S. cattle herd size has been shrinking since the mid-1990's and is at the lowest level since 1958, with an inventory of 92 million head (Mintert et al., 2003). As the economy improves, consumers desire more and better quality protein, increasing the consumer demand for beef. As demand rises, producers are forced to improve the efficiency and quality of the beef to meet the market demands of their product (Mintert, 2003).

Although the inventory of cattle is historically low, the productivity of beef cattle has increased (Mintert, 2003). Great strides have been made to get more beef out of every pound of feed fed to cattle (Elam, 2011). The use of feed additives, breeding and genetics, parasite control, health programs, management, feed formulation, and growth-promoting implants have proved to increase the efficiency of (Elam, 2011).

Along with improving the efficiency of cattle and feed conversion come the challenges of improving cattle uniformity, beef consistency, and carcass quality (Shook et al., 2008). The National Beef Quality Audits (NBQA) of the 1990's shows that the main quality concerns of packers were lack of uniformity in live cattle and hide damage (Shook et al., 2008). The 2005 NBQA indicated that there were improvements in the incidence of bruises and the uniformity of cattle; however, packers' main concerns once again included lack of overall uniformity in live cattle, the presence of injection-sire lesions, and insufficient marbling (Shook et al., 2008). The U.S. is the world's largest beef exporter and has a superior reputation in foreign markets for an excellent beef flavor; however, low USDA quality grade (QG), as well as the incidence of USDA yield grade (YG) 4 and 5 carcasses, continue to be cattle producers' greatest areas of concern (Shook et al., 2008). Although beef producers have made great strides to improve the quality of their product over the past years, improvements still need to be made to improve the quality and flavor of beef produced in the United States (Shook et al., 2008). A 2005 NBQA questionnaire asked producers, "What would be one quality characteristic U.S. cattleman could change to make it easier for them to export beef product?" Two of their top five responses included "insufficient marbling" and "administration of growth-promoting implants causing low quality grades" (Shook et al., 2008; Smith et al., 2007). Beef exporters listed carcass quality as their second most challenging obstacle to overcome in the exportation of U.S. beef (Smith et al., 2007).

Carcass Quality

USDA quality grade data suggests that there has been a dramatic decline in the QG of beef produced in the U.S. over the last 20 years (Rhoades et al., 2008). Producers are concerned that value of their product is being lost as the percentage of Select-grade beef increases and the percentage of Choice-grade declines and the Choice-Select spread rises with the increasing trend of the value-based marketing of beef (Rhoades et al., 2008). Hughes (2002) reported there has been a 36% decline in the incidence of Choice grade beef, resulting in an increase in the prevalence of Select grade carcasses. Further, USDA grading proportion data shows that the percentage of Choice carcasses has dropped from 79.0 to 57.2% from 1991 to 2005 (Rhoades et al., 2008), and this decline may be partly due to aggressive implant regimens and increased feeding of yearlings vs. calves (Beck et al., 2012).

Beef Quality grades (USDA, 1997) are designed to sort beef into expected eating (i.e., tenderness, juiciness, and flavor) categories (Tatum, 2007). The 8 USDA Quality grades include Prime, Choice, Select, Standard, Commercial, Utility, Cutter, and Canner. Physiological maturity of the carcass and marbling, or intramuscular fat, are evaluated to determine the quality grade of a carcass (Tatum, 2007). Visible indicators are used to classify cattle into groups categorizing their stage of physiological maturity (Tatum, 2011). Some visible indicators include ossification of the bones, size and shape of the ribs, and cartilage along the vertebral column of the spilt carcass (Tatum, 2011). As the chronological and physiological age of cattle increases, beef becomes tougher because of increased mechanical and thermal stability of collagen, which is the primary connective tissue protein that provides the framework within the skeletal muscles (Tatum, 2011). As cattle mature, their meat becomes progressively tougher; therefore Quality Grade is adjusted downward because of the reduction in tenderness (Tatum, 2007). Cattle less than 18 months of age produce beef that contains immature, soluble, intramuscular collagen which results in more tender beef (Tatum, 2011).

The groups of physiological maturity that cattle can be grouped in are identified as A through E, with the majority of conventionally-produced, grain-finished cattle slaughtered being classified as A-maturity (9 to 30 months of age) (Tatum, 2007; Garcia et al., 2008). After the maturity of a carcass is established, the marbling within the LM is evaluated, which is the primary determinant of the quality grade of the carcass (Tatum, 2007). LM with a high degree of marbling will result in a high quality grade, indicating that an enjoyable eating experience and a great amount of tenderness, juiciness, and flavor is expected of the cut of beef (Tatum, 2007).

Along with age, the sex of a calf also plays a part in the rate of physiological maturity in cattle. It has been shown that estrogen promotes skeletal ossification, and females of various mammalian species exhibit signs of more advanced bone maturity than males of the same age (Grumbach and Auchus, 1999).

Yield grades (USDA, 1997) are used to estimate the cutability (percentage of boneless, closely trimmed retail cuts from the round, loin, rib, and chuck) of a beef carcass (Tatum, 2007). Yield grades (YG) range from 1 through 5, with a YG 1 representing the greatest yield of closely trimmed, boneless retail cuts. External fat thickness over the LM, LM area, estimated percentage of kidney, pelvic, and heart fat (**KPH**), and hot carcass weight (**HCW**) are all used to determine YG of beef carcasses. The occurrence of numerically greater YG in recent years is likely a result of younger, and/or lighter, cattle entering the feedlot (Barham et al., 2012).

Effect of Management

Management can affect the quality of carcasses in several ways, including stress, vaccination, early weaning, age, nutrition, and implant strategies. When predicting the finishing performance of feeder cattle, body composition, previous plane of nutrition, BW, breed type, and age must all be considered (McCurdy et al., 2010). Cattle that have been fed on a high plane of nutrition or fed on an energy dense diet prior to entry into the feedlot have been shown to be fatter for all measures of carcass composition when entering into the finishing phase compared with cattle that have been nutritionally restricted (Baker et al., 1992). Cattle that have a higher percentage of body fat when entering into the feedlot are assumed to have a less efficient rate of feed conversion and a lower rate of gain in the finishing phase (NRC, 1996). Fatter feeder cattle typically receive lower sale prices at the sale barn because of expected reductions in ADG in the feedyard (Smith et al., 2006). However, McCurdy et al. (2010) reported that fatter calves at the entry into the feedyard did not experience a reduction in ADG; rather, they had greater ADG and G:F when compared with the calves that were leaner upon entry into the feedlot. McCurdy et al. (2010) reported that calves with a greater amount of fat at entry into the feedlot had greater gains of carcass protein and energy during the finishing phase.

While many cattle often go into a backgrounding or stocker phase after weaning; some cattle are entered directly into the feedlot post-weaning for finishing, commonly referred to as an intensive 'calf-fed' system (Griffin et al., 2007). In calf-fed systems, cattle are fed an energy-dense, high-concentrate diet from weaning until slaughter. Heavier calves may be best suited for this intensive system in order to maximize profit and performance potential (Griffin et al., 2007). Calf-feeding production systems can result in improved feed efficiency, but the potential for lighter BW and more days on feed are greater than in an extensive, pasture-based yearling finishing system (Turgeon, 1984).

Economic comparisons indicate that calves undergoing a stocker phase and finished as yearlings are more economically efficient. Griffin et al. (2007) found that, when comparing cattle of equal fat thickness, yearlings had greater ADG than calf-fed cattle, and required fewer days on feed to produce a carcass with a better QG, along with depositing intramuscular fat at a greater rate. Cattle fed as calves often produce fatter, numerically greater YG carcasses, but in many instances, the QG was equal to, or greater than, cattle fed as yearlings (Smith and Lunt, 2007).

Effect of Implants

Implants are used to increase economic returns by reducing the cost of beef cattle production (Duckett and Andrae, 2001). Because anabolic growth-promoting implants have a positive effect on the ADG of cattle, the use of implants in the beef industry has been adopted as a routine management practice (Roeber et al., 2000). Implants are most commonly used in the stocker and feedlot sectors of the industry.

Implants commonly consist of powder that has been compressed into a small pellet and inserted under the skin on the backside of the calf's ear. Natural or synthetic anabolic compounds are released over time into the bloodstream and act similar to naturally-occurring hormones, causing the animal to respond physiologically as if the compounds were produced naturally by the animal (Apple et al., 1991).

Implants first were approved in the 1950's and are widely used today; during the finishing phase, with over 96% of all feedlot cattle having been implanted one or more times (USDA, 2000; Duckett and Andrae, 2001). Implants have the potential to improve carcass leanness by up to 8% compared to nonimplanted calves with the same body weight, as well as improving feed efficiency by 15 – 30% (Bruns et al., 2005). Bruns et al. (2005) showed that steers receiving an implant had 10.5% improved feed efficiency compared to cattle that were not implanted. Implants improve efficiency of meat production by improving red meat yield.

Anabolic implants are either androgenic, estrogenic, or a combination of both androgenic and estrogenic. Implants work to increase muscle protein accretion and decrease protein degradation in cattle (Morgan, 1997; Webb et al., 2002). Androgenic compounds mimic the effects of the naturally-occurring hormone testosterone; whereas estrogenic compounds mimic the effect of estrogen (Duckett and Andrae, 2001).

Physiologically, anabolic implants affect specific muscles and fiber types within muscles in the body (Maltin et al., 1990). In cattle, a response to growth hormones (GH) regulated by steroids are responsible for muscle protein accretion (Beerman et al., 1991). Protein synthesis is increased while protein degradation is decreased in cattle that have been implanted (Nichols et al., 2002). According to Preston (1987), steroidal implants are the best non-nutritional management tool available to increase biological and economical efficiency of beef cattle.

Hutcheson et al. (1997) reported that the use of androgen-estrogen combination implants exhibited an additive effect on protein deposition compared with using either an estrogenic or androgenic implant alone, indicated by an increase in empty body weight protein. Furthermore, Bruns et al. (2005) also reported that cattle given combination implants increased ADG and feed efficiency more than cattle given either substance alone.

Implants are designed to increase nitrogen retention and improve growth rate of cattle (Hutcheson et al., 1997). Visceral organs are some of the most metabolically active tissues within the body, and their weight may increase due to the use of implants (Hutcheson et al., 1997). As these organs increase in size, the animal's net energy for maintenance could be elevated (Johnson et al., 1990). In a study by Hutcheson et al. (1997), steers that received any implant had larger livers than did non-implanted control steers, and steers that were implanted with combination implants had the heaviest livers. It is estimated that 21% of the total energy expenditures in the body are consumed by the liver (Hutcheson et al., 1997). In that study, anabolic implants increased growth by accelerating nutrient deposition as protein, but not at the expense of fat. Implanted cattle were estimated to gain 27 to 64% more protein than nonimplanted, control steers (Hutcheson et al., 1997).

Different implants are formulated to release compounds into the bloodstream of cattle over different amounts of time. The period during which the implant is effective is commonly referred to as the payout period, which can last anywhere from 60 to 400 days (Lehmkuhler and Burris, 2010). The payout period of the implant can be affected by proper administration of the implant into the ear, the formulation of the implant, and amount of blood flow to the ear.

Before entering the feedlot, weaned calves are often placed into a backgrounding or stocker program to achieve adequate frame size before entering the finishing phase as yearlings. In this extensive system, calves are commonly grazed on forage or crop residue through the winter or fed harvested forages or crops (Griffin et al., 2007). Cattle implanted in the stocker phase can have an improved ADG of 15% (Duckett and Andrae, 2001).

Improved ADG and feed efficiency result with implant use in the feedlot industry. Feedlot steers that were implanted improved in ADG by 18% and feed efficiency by 8% compared with cattle that were not implanted (Duckett et al., 1996). Use of growth-promoting implants in finishing steers has been shown to increase the amount of protein in the empty body, improve ADG, and shift the growth curve toward heavier weights at equal fat percentages compared to steers that were not implanted (Hutcheson et al., 1997). Beck et al. (2012) reported that steers and heifers aggressively implanted prior to and during finishing were more profitable than cattle whose implant was delayed until the midpoint of finishing, even though carcass quality was reduced. This increase in net return was primarily due to increased HCW and reduced cost of production.

Although growth implants have been proven to increase feed efficiency and increase LM area, they may reduce tenderness and palatability of steaks from implanted cattle. The cattle industry in the United States adopted the use of implants to increase growth rates and reduce costs of live weight gain because of market incentives (Roeber et al., 2000). Researchers pointed out at the 1994 National Beef Tenderness Conference that "one of every four steaks is less than desirable in tenderness and palatability and that every tough carcass affects as many as 542 consumers" (Myers et al., 1999). Although shown to increase HCW and LM area, implants can decrease the palatability of beef, causing a less than desirable eating experience for the consumer (Roeber et al., 2000). Tenderness can depend on type of implant used and implantation strategy. Roeber et al. (2000) reported that steaks from implanted steers were less tender and juicy than steaks from nonimplanted steers. Furthermore, Platter et al. (2003) indicated that "the closer the implant strategy was applied to slaughter, the more likely shear values would be affected," whereas Bruns et al. (2005) reported similar findings, stating that the administration of implant too close to slaughter will decrease the amount of marbling in the carcass. Roeber et al. (2000) also found that consumers rated steaks from steers that were not implanted as more tender than those of steers that were implanted, except for steaks from cattle implanted with the Encore and Component T implant. Also shown by Roeber et al. (2000), anabolic growth promotants can compromise beef carcass quality grades due to reduced marbling scores and increased incidence of dark cutters. In a study by Duckett et al. (1999), implantation reduced marbling score by one-half of a marbling degree compared with controls that were not implanted.

Implantation can also have an effect on skeletal maturity, which can have a negative correlation with quality grade (Tatum, 2011). Combination implants that are steer-specific usually contain a 5:1 ratio of TBA to estradiol and heifer-specific implants contain a 10:1 ratio of TBA to estradiol, causing the maturation of the skeleton of cattle to be accelerated by this estrogen-like compound. This acceleration of skeletal maturation appears to be directly linked to the estrogenic effects of zeranol or estradiol found in the implants (Tatum, 2011).

Paisley et al. (1999) found that when cattle are implanted multiple times and experienced an extended period of restricted growth on forage and then finished as yearlings, there was significant skeletal maturation, which can result in a substantial increase in the incidence of B-maturity, or older, carcasses and decreases in QG. However, the relationship between beef tenderness and animal age was examined among steers and heifers harvested between 300 to 699 days of age and it was determined that age was not an important determinant of meat tenderness among heifers and steers that were less than two years of age (Field et al., 1966).

Potency of the implant can affect carcass quality. In steaks from heifers implanted with implants containing a greater cumulative estradiol benzoate, there was a linear increase in Warner-Bratzler shear force (**WBSF**) values compared with heifers implanted with a low-potency implant (Scheffler et al., 2003). A review of several studies on the effects of steroidal implants on tenderness of beef does not depict a clear relationship between increasing implant potency and a reduction in tenderness (Nichols et al., 2002).

Bruns et al. (2005) indicated that the timing of the implant may be as important as the potency. Carcasses developed marbling scores similar to nonimplanted contemporaries if a lower-potency implant was administered early in the finishing phase. Steaks from carcasses of steers that had been implanted with combination implants twice, as the initial and terminal implant, or three times, as the initial, intermediate, and terminal implant, had greater WBSF values than steaks from cattle that had not been implanted (Samber et al., 1996). However, Samber et al. (1996) also reported that cattle that had been implanted with an estradiol implant initially, followed by a combination implant did not differ in WBSF values from cattle that were not implanted. The same study reported that cattle that were implanted with two doses of an estradiol implant initially and intermediately, followed by a terminal combination implant, or one dose of an estradiol implant followed by 2 doses of the combination implant resulted in no difference of WBSF compared with cattle that had not been implanted (Samber et al., 1996). A review of the effect of implants on tenderness (Nichols et al., 2002) indicated that the results currently available show limited, if any, effects of multiple implants on beef tenderness.

Breed type and implant strategy may interact, having an effect on tenderness and palatability of the carcass. Roeber et al. (2000) showed that steaks from British steers treated with a combination implant followed by no implant had greater WBSF values than steaks from steers that had never been implanted. Growth implants used in animals with greater growth potential in an effort to increase the rate of growth of that animal may compound any tenderness problems that would have occurred due to the implant (Boles et al., 2009). A greater muscle-to-bone ratio is already present in late-maturing, heavily-muscled animals, indicating a reduced amount of protein degradation and a greater amount of protein accretion compared with earlier-maturing, light-muscled calves (Boles et al., 2009). Apple et al. (1991) reported that Holstein steers that were implanted with trenbolone acetate plus estradiol benzoate and progesterone may result in a lower percentage of carcasses grading USDA Choice.

Sex also has an effect on the palatability of beef from implanted animals. In a study by Boles et al. (2009), steers had a greater response to the implants than did heifers, with carcass weight of steers increasing approximately 47 kg, whereas heifer carcasses increased only 5 kg. However, both steers and heifers that were implanted had a greater HCW and longissiums dorsi area compared with cattle that were not implanted.

Another management strategy used to maximize efficiency of cattle in the feedlot can be managing feed intake or using a programmed feeding system for specific rates of gain before entry into the feedlot (Galyean, 1998). Restricted or programmed feeding has the potential to decrease costs by avoiding over-consumption of feed by cattle starting on feed, decreasing bunk management costs, decreasing manure loads, and increasing feed efficiency (Scaglia et al., 2004). According to Samber et al. (1996), delaying the first implant application as well as managing the rate of gain of steers can improve performance (ADG and efficiency of gain) and carcass quality and composition.

Although studies have shown implantation to have a negative effect on carcass quality and consumer acceptability, Barham et al. (2003) reported that untrained consumers failed to detect a difference among beef that had different implant regimens during production after steaks were aged 7 and 14 days. Using a modern implant program, such as implanting two times before harvest, does not seem to impact consumer acceptability and beef tenderness (Barham et al., 2003). Barham et al. (2012) indicated that aggressively implanting cattle with higher genetic potential to marble during a restricted growth phase and during the finishing phase experienced 50% reduction in percentage Choice and reduced marbling score compared with cattle whose initial implant was delayed until the midpoint of the finishing phase. Carcass quality grade and marbling score of cattle with limited genetic potential for marbling were not affected by implantation.

GrowSafe Systems Ltd.

Implantation of cattle can cause an increase in appetite, resulting in increases in DMI. GrowSafe Systems Ltd. is an automated feeding system that enables continuous individual feed intake data acquisition in real-time. Each animal is individually tagged with an electronic identification tag, and when an animal is present at the feed bunk, a reading is taken every second to determine animal presence. Load sensors are continuously sampled to record meal, bite size, and error from natural elements such as rain, wind, and snow are continuously calculated. The use of a GrowSafe system can enable precise intake and feeding behavior data collection, providing scientists the capability to more accurately determine dry matter intake and feeding efficiency of cattle.

The GrowSafe System has been proven accurate and effective for measuring feed intake over a period of time (Wang et al., 2006). Animal efficiency can be determined by residual feed intake (RFI), a moderately-heritable trait that measures the difference between an animal's actual feed intake and its expected feed requirements for maintenance and production (Wang et al., 2006; McDonald et al., 2010). An improvement in feeding efficiency by 5% could reduce feedlot breakeven prices by $3.50/cwt and grazing costs by $10.80/yr/cow (McDonald et al., 2010). Feed intake was measured in a study by McDonald et al. (2010) with bulls and feeding behavior was evaluated in the GrowSafe System in a study by Mendes et al. (2011). Feeding behavior can be evaluated to examine variation in feed efficiency, understand mechanisms controlling feed regulation, and predict health status of animals (Mendes et al., 2011). Schwartzkopf-Genswein et al. (2011) reported that steers with high and average ADG tended to consume more feed than low ADG steers and frequency of bunk visits was least for high ADG cattle.

Ultrasound

In beef cattle, fat in the body is accumulated first in the kidney, pelvic, and heart (KPH) and gastrointestinal region. Following the deposition of KPH and gastrointestinal fat, fat is next deposited intermuscularly, subcutaneously, and intramuscularly (Gerrard and Grant, 2003). Factors affecting the rate of fat deposition include sex, breed type, and level of nutrition (Ribeiro et al., 2008). The amount of body fat on the animal is a component of yield grading, and by knowing the amount of back, intramuscular, rump, and KPH fat prior to slaughter, a producer is better able to make better production decisions. Fat thickness is also among the most important aspect of carcass yield grade, so ultrasound technology can be used to project future cutability of cattle (Brethour, 1992).

Ultrasound technology is a useful, objective method to estimate carcass attributes of the live animal and in determination of the proper harvest time to optimize market profits. This technology has the potential to increase income by shortening the length of the finishing period and avoiding wasting feed resources (Brethour, 1992).

Real-time ultrasound can be used to assess carcass characteristics on the live animal (Ribeiro et al., 2006). It is a non-invasive technique that requires the animal to be immobilized for only a short period of time. Ultrasound technology is a highly repeatable technique that, along with indicating the amount of fat on an animal, is also useful in the indication of longissimus muscle area (Ribeiro, 2008).

Although the impact of implant strategies, plane of nutrition, and age entering the feedlot on carcass quality have been extensively studied in the field of animal science, few studies have reported the interaction of all of these in the determination of carcass quality and consumer acceptance.

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CHAPTER III

ABSTRACT

Implant strategy and nutrient restriction prior to finishing may alter feedlot performance, as well as carcass characteristics and consumer acceptability of beef. The objectives of these studies were to determine the effect of prefinishing implant strategy and plane of nutrition on prefinishing and feedlot performance, carcass characteristics, beef quality, and consumer acceptability of beef. Spring-born calves were weaned in the fall (Exp. 1, n =120; and Exp. 2, n = 96) and either finished as calves (CALF-FED) or placed on a growing program with a target ADG of 0.45 kg/d (RSTR) or 0.91 kg/d (UNRSTR) before finishing. Half of each backgrounding group received moderate-potency hormonal implants with 200 mg progesterone and 20 mg estradiol benzoate (Synovex-S; Pfizer Animal Health, Madison, NJ) for steers or 200 mg testosterone propionate and 20 mg estradiol benzoate (Synovex-H; Pfizer Animal Health) for heifers before finishing (IMPL). Upon arrival to the feedyard all cattle were implanted with a moderate-potency implant and were reimplanted following 100-d (CALF-FED) or 81-d on feed (UNRSTR and RSTR). Animal performance and carcass characteristics data were analyzed as a split-plot design using the Mixed procedure of SAS. Treatment least-squares means were separated using predicted differences. Implantation prefinishing positively affected ($P < 0.01$) ADG in UNRSTR cattle in the feedlot in Exp. 1, and in all growth treatment groups ($P < 0.01$) in Exp. 2. Cattle in the UNRSTR treatment had greater ($P < 0.01$) HCW than CALF-FED or RSTR in both experiments, but there was no effect ($P = 0.38$) of implant on HCW. Cattle fed as calves had a greater ($P = 0.02$) marbling scores than yearlings in Exp. 1, but there were no differences ($P = 0.32$) in marbling scores across treatments in Exp. 2. In Exp 1, IMPL cattle tended ($P = 0.06$) to have a lower marbling score and had reduced ($P = 0.03$) percentage of cattle grading

Choice; however, there was no effect ($P \geq 0.32$) of implant strategy on the percentage of cattle grading Choice or on marbling score. Furthermore, cattle receiving an implant prefinishing had less ($P \leq 0.03$) initial and sustained tenderness than cattle that received a delayed implant in Exp 1 and 2.

Key Words: carcass quality, feed efficiency, implant, nutrient restriction, tenderness

INTRODUCTION

Several different aspects of cattle management can affect the quality of beef carcasses, including age entering the feedlot, implant strategy used, and plane of nutrition prior to finishing. Cattle that have been fed on a high plane of nutrition, or fed on an energy-dense diet, prior to entry into the feedlot have been shown to be fatter when entered into the finishing phase compared with cattle that have been nutritionally restricted (Baker et al., 1992). Cattle commonly go through a stocker phase of production where they are grown on pasture until they enter the feedlot and finish as yearlings; yet, other cattle may begin the finishing phase directly after weaning and are finished as calves, or "calf-fed" (Griffin et al., 2007). Furthermore, Griffin et al. (2007) found that when comparing cattle of equal fat thickness, yearlings had fewer days on feed to produce a quality carcass, along with depositing intramuscular fat at a greater rate and having greater ADG compared with calf-fed animals. Cattle fed as calves often produce higher yield grade carcasses, but in many instances the quality grade has been equal to, or greater than, cattle fed as yearlings (Smith and Lunt, 2007).

Anabolic implants were first used in cattle production systems in the United States in the 1950's to accelerate BW gains, improve carcass leanness, increase red meat yield, and improve feed efficiency. However, with the benefits of using steroidal implants come potential negative impacts on tenderness, intramuscular fat, palatability, and flavor of beef can occur as a result of implantation, causing less than desirable eating experience for the consumer (Roeber et al., 2000). There is limited evidence available reporting the interaction of implants, plane of nutrition, and backgrounding phase with one another. Thus, the objectives of Experiments 1 and 2 were to determine the relationship between implant status and energy balance prefinishing and their effects on prefinishing and finishing phase performance, carcass quality characteristics, and sensory panel evaluations of cooked beef palatability.

MATERIALS AND METHODS

All animal procedures in the following experiments were reviewed and approved by the University of Arkansas Institutional Animal Care and Use Committee. Cattle used for both experiments originated from the University of Arkansas Southwest Research and Extension Center (SWREC; Hope, AR) from the spring-calving cow herd of predominant (75-87%) Angus ancestry. Prior to the start of each experiment, all calves were genotyped using Igenity (Merial Animal Health), and a panel of several markers were used to determine specific genotypes or panel scores for marbling. The results were balanced across the age and implant treatments to allow for the estimation of age and implant treatment effects on a specific genotype.

Experiment 1

Heifer and steer calves (n = 120) were weaned at 7 months of age and preconditioned for 28 days at the SWREC feedlot facility. Growth treatments included: 1) cattle fed as calves (**CALF-FED**, n = 40), which were placed on mixed growing rations to produce estimated ADG of 1.15 kg/d for 45-d prior to being shipped to the feedyard; 2) Restricted intake yearlings (**RSTR**, n = 40), cattle limit-fed a restricted growing diet for 106 days with a goal ADG of 0.45

kg/d then placed on cool-season annual pasture for 64 days; and 3) Unrestricted intake yearlings (**UNRSTR,** n = 40), calves were limit-fed growing diets sufficient for gains of 0.9 kg/d for 36-d, then placed on cool-season annual pastures for 136-d. Cattle were allocated by gender and BW to pens (n = 4 pens/treatment; n = 10 calves per pen).

Half of the cattle in each finishing group (**IMPL**) received a moderate potency implant with 200 mg progesterone and 20 mg estradiol benzoate (Synovex-S; Pfizer Animal Health, Madison, NJ) for steers or 200 mg testosterone propionate and 20 mg estradiol benzoate (Synovex-H; Pfizer Animal Health) for heifers during the growing and feeding phase and the other half of each feeding group (**DELAY**) received an initial implant upon arrival to the feedlot at the end of the prescribed pre-finishing period for each treatment (CALF-FED, Dec. 9, 2009; UNRSTR and RSTR, Apr. 22, 2010).

Diets fed to CALF-FED for the 45-d preconditioning period were based on warm-season grass hay and ground corn and soybean hulls as the primary concentrate energy sources (Table 1). The CALF-FED cattle were started on 40% roughage and the roughage level was stepped down at 2-wk intervals to 30% roughage and finally 20% roughage levels. Cattle in UNRSTR treatment were program-fed the 40% roughage diet (Table 1) from Nov. 3 to Dec. 9, 2009, for an ADG of 0.9 kg/d. Cattle in UNRSTR groups were then placed on 4 pastures (10 ha/pasture) of wheat (Triticum aestivum L.) and annual ryegrass (Lolium multiflorum L. spp (Lam.) Husnot) interseeded into bermudagrass (Cynodon dactylon [L.] Pers.) until Feb. 19, 2010. On Feb. 19, 2010, UNRSTR were relocated to 4 groups and placed on pastures at a stocking rate of 2 animals/ha until cattle were shipped for finishing on Apr. 22, 2010. Cattle in RSTR were fed long-stem warm season grass hay (predominantly bermudagrass) and 0.9 kg corn/soy hull supplement for 108-d (from Nov. 3, 2009 to Feb 19, 2010) with a goal of approximately 0.45

kg/d ADG. On Feb. 19, 2010 cattle were placed on wheat-ryegrass pastures (n = 4 pastures) at a stocking rate of 2 animals/ha.

All groups of cattle were shipped 597 km to a commercial feedyard (Alfadale Stock Farm, El Reno, OK). At the feedyard, cattle were divided by gender and fed steam-flaked corn-based finishing diets (Table 2) in mixed treatment groups until the average backfat thickness for each group reached 1 cm. Cattle were then transported 491 km to Cargill Red Meat Solutions (Plainview, TX). Final diets fed during finishing can be found in Table 2.

Experiment 2

Treatments and management prefinishing were as described above for Exp. 1. Moreover, CALF-FED were fed diets (Table 1) in drylot pens for 42 d prefinishing as described for Exp 1 prior to transport for finishing on Dec. 14, 2010. Cattle in RSTR were limit-fed 40% roughage diet for 0.45 kg/d ADG and UNRSTR were limit-fed 40% roughage diet for 0.9 kg/d ADG from Oct. 20 to Nov. 29, 2010. On Nov. 29, 2010, UNRSTR and RSTR were placed on wheat and annual ryegrass pasture at stocking rates of 0.7 ha/calf and 0.3 ha/calf for UNRSTR and RSTR, respectively, to promote ADG of 0.9 and 0.45 kg/d, respectively. Yearling finishing groups (UNRSTR and RSTR) were transported for finishing on May 5, 2011. One half of each growing phase treatment received a moderate potency implant as described for Exp. 1 at the start of preconditioning and re-implanted at the mid-point of the grazing period, and one half of each feeding group (**DELAY**) did not receive an implant until arrival at the feedlot.

All cattle in Exp. 2 were shipped to The Samuel Roberts Noble Foundation (Ardmore, OK) Oswalt Ranch for finishing at the end of the backgrounding period. Diets fed during finishing consisted of a whole corn, dried distiller's grain, and cotton seed hulls-based diet, containing 15.5 % CP, 2.1 mcal NEm/kg, and 1.4 mcal NEg/kg (Table 3). Cattle were fed during the finishing phase using the GrowSafe System (GrowSafe Systems Ltd., Alberta, Canada) which allowed for individual animal intake and feeding behavior of feed and water. Upon arrival to the feedyard, each treatment group received a moderate potency implant (Synovex S/H, Fort Dodge Animal Health, Fort Dodge, IA) and calves were fed in a single group on a whole corn and dried distillers grains based diet until their average backfat thickness reached 1 cm, determined by ultrasound. Cattle were ultrasounded at the initiation, midpoint, and end of the feeding period to determine proper harvest endpoint.

Carcass Data Collection and Sampling

Carcass quality data were collected by trained personnel from Texas Tech University, (Lubbock), and boneless strip loins were collected from one side of each carcass. Hot carcass weights were obtained prior to carcasses being subjected to a 36-h spray-chill period. Carcasses were ribbed at the 12^{th} and 13^{th} rib interface and USDA Quality and Yield grade data were collected approximately 48-h postmortem. Sensory and Warner-Bratzler shear force (**WBSF**) evaluation was performed after strip loins were wet aged 14 days prior to fabrication into 2.5-cm-thick LM steaks. Beginning at the anterior end of each strip loin, the first steak was designated for proximate analysis and measurements of collagen content. The next steaks were alternately assigned to WBSF determination (1 steak/strip loin) or trained sensory panel evaluations (at least 2 steaks/strip loin).

Steaks for WBSF determinations were thawed at 4ºC for 24 h before all external fat was removed. Then, steaks were cooked to an internal temperature of 71°C on a Magi-grill belt grill (model TBG-60; Magi-Kitch’n Inc., Quakertown, PA) according to AMSA (1995) guidelines.

Once steaks exited the belt grill, final internal temperature was measured with a digital meat thermometer (model SH66A; Cooper Instruments, Middlefield, CT) to ensure the final endpoint internal temperature of 71°C. Each cooked steak was placed on a metal tray, wrapped in an oxygen-permeable, polyvinyl chloride film, and chilled for 24 h at 2°C before six 1.27-cm-diameter cores were removed from each LM parallel to the muscle fiber orientation. Then, each core was sheared through the center and perpendicular to the muscle fiber orientation with a WBSF machine (G-R Manufacturing Co., Manhattan, KS). Individual core readings were monitored by a digital force gauge (model BFG500N; Mecmesin Corp., Sterling, VA), and the average of the 6 cores was used for statistical analyses.

Proximate Analysis and Sensory Evaluation

Steaks were thawed at 2 to 4° C for 24 h, all external fat and epimysial connective tissues were removed, and steaks were homogenized in a food processor (model KP26MIXER, KitchenAid USA, St. Joseph, MI). Protein, moisture, fat, and collagen contents of each sample were individually measured using an AOAC-approved (method 2007.04) near-infrared spectrophotometer. For statistical analysis, 15 readings were taken and averaged for each sample.

Steaks designated for sensory panel evaluation were thawed at 4° C for 24 h before all external fat was removed and steaks were cooked to an internal temperature of 71° C as previously described for WBSF determination. Immediately after cooking, steaks were cut into 1-cm^3 cubes and served warm to trained sensory panelists. Samples were evaluated by a 6- to 8-person trained panel twice daily. According to AMSA (1995) guidelines, trained panelists evaluated each steak sample for initial and sustained juiciness (1 = extremely dry to 8 =

extremely juicy), initial and sustained tenderness (1 = extremely tough to 8 = extremely tender), beef flavor intensity (1 = extremely bland to 8 = extremely intense), off-flavor (1 = uncharacteristic beef flavor to 8 = characteristic beef flavor), and overall mouthfeel (1 = non-beef-like mouthfeel to 8 = beef-like mouthfeel).

Statistical Analysis

Animal performance, carcass data, proximate analysis, WBSF, and sensory panel analysis were analyzed as a spilt plot design using the Mixed models procedure of SAS (SAS Inst., Inc., Cary, NC). Pen within treatment was used in the random statement and gender was used as a covariate in all data analyses. Interactions were considered significant when $P \leq 0.10$. Panelist within each sensory session was included as a random effect in the analysis of the trained sensory panel data. In the absence of interactions between gender and other factors ($P > 0.10$), analysis of the effects of growth treatment implant frequency were pooled across gender, and, when the interaction between age and implant was significant ($P \leq 0.05$), least-squares means were separated by the PDIFF option in SAS.

RESULTS AND DISCUSSION

Prefinishing Phase Performance

Experiment 1

The effects of age entering the feedlot, prefinishing implantation, and prefinishing nutrient status on performance during backgrounding in this experiment are presented in Table 4. There was no difference ($P = 0.95$) in the initial BW of cattle among backgrounding treatments; however, cattle that were implanted prefinishing had greater ($P < 0.01$) BW at shipping to the feedlot than DELAY, and CALF-FED cattle had lighter ($P < 0.01$) BW at feedlot entry than RSTR cattle. Moreover, RSTR cattle weighed less ($P < 0.01$) at shipping than UNRSTR. Implanting cattle during the stocker phase can have an improved ADG by as much as 15% (Duckett and Andrae, 2001). Average daily gain during prefinishing for cattle that received an implant during backgrounding was greater ($P < 0.01$) than that of cattle that were not implanted until finishing. By design, while on pasture during the prefinishing phase, UNRSTR cattle had greater ($P < 0.01$) ADG than RSTR cattle and greater ($P < 0.01$) total gain than the RSTR group during the backgrounding phase. Cattle that have been fed on a high plane of nutrition during backgrounding have been shown to be fatter for all measures of carcass composition when entered into the finishing phase compared with cattle that have been nutritionally restricted (Baker et al., 1992). During prefinishing, cattle also had a significant response to implantation with the DELAY cattle gaining less total weight ($P = 0.04$) than cattle that received the implant during the backgrounding period.

Experiment 2

The effects of age entering the feedlot, prefinishing implantation, and prefinishing nutrient status on performance during backgrounding in this experiment are presented in Table 4. Similar to results of Exp. 1, there were no ($P \geq 0.10$) background x implant interactions for initial BW, BW at shipping, ADG, or total gain ($P > 0.10$). There was no difference ($P = 0.96$) in the initial BW of cattle among treatments. Cattle in UNRSTR were heaviest ($P < 0.01$) at shipping, followed by RSTR, and CALF-FED cattle were lightest ($P < 0.01$) at time of shipping to the feedyard. Cattle that were implanted had greater ($P < 0.01$) ADG during backgrounding than did DELAY, whereas cattle in UNRSTR group had greater ($P < 0.01$) ADG than did RSTR cattle. During the prefinishing phase, UNRSTR treatment group had the greatest ($P < 0.01$) total weight gain, followed by RSTR cattle, and CALF-FED calves had the least total BW gain ($P < 0.01$). Implanted cattle gained more ($P < 0.01$) per day and during the total prefinishing period compared with DELAY. Similar results were found in a study by Paisley et al. (1999) where cattle that were implanted while grazing dormant native range had a greater gain of 8 kg than nonimplanted cattle. Minimal implant response is expected from cattle that have been implanted on a low plane of nutrition (Scaglia et al., 2004); however, in this experiment RSTR cattle experienced a similar response to prefinishing implantation as UNRSTR cattle ($P = 0.65$), which were on a high plane of nutrition. As expected, cattle on a low plane of nutrition (RSTR) did not have a great response to prefinishing implantation, which was largely due to the lack of nutrients available for muscle protein accretion after implantation.

Finishing Phase Performance

Experiment 1

The effects of age entering the feedlot, prefinishing implantation, and prefinishing nutrient status on performance during finishing are presented in Table 5. There was no implant x background interaction ($P = 0.98$) for initial and final finishing BW, finishing ADG, days on feed, or total BW gain. Calves that received a prefinishing implant entered the feedyard at a greater ($P = 0.02$) BW than DELAY. Furthermore, UNRSTR entered the feedyard at the heaviest ($P < 0.01$) weight, followed by RSTR, and CALF-FED calves entered the feedlot at the lightest BW ($P < 0.01$). Unrestricted growth yearlings had the greatest ($P < 0.01$) ADG in the feedyard, followed by RSTR yearlings, and CALF-FED cattle had the least ($P < 0.01$) BW gain per day during feeding. Similarly, McCurdy et al. (2010) reported cattle that had a greater amount of body fat at the entry into the feedyard had greater gain of carcass protein and energy during the finishing phase. There was no implant effect ($P = 0.15$) on ADG during finishing. However, Duckett et al. (1996) reported that implanting cattle at entry into the feedyard can result in an improvement of ADG by up to 18% and an improvement in feed efficiency by 8% compared with cattle that received no implant at entry into the feedyard. As expected, cattle in the UNRSTR treatment had fewer ($P < 0.01$) days on feed than RSTR treatment, and CALF-FED cattle were on feed the longest ($P < 0.01$). There was no implant effect ($P = 0.75$) for days to harvest. Cattle finished as calves had the greatest ($P < 0.05$) total gain while in the feedlot and RSTR had greater ($P < 0.05$) total gain than did UNRSTR. Unrestricted yearling cattle had the greatest ($P < 0.01$) final BW at slaughter and CALF-FED had the least BW at slaughter ($P = 0.01$).

Experiment 2

The effects of age entering the feedlot, prefinishing implantation, and prefinishing nutrient status on finishing performance for Exp. 2 are presented in Table 5. There was no background x implant interactions ($P > 0.10$) for initial BW, ADG, feed efficiency, DMI, or final BW ($P < 0.10$). As observed in Exp. 1, UNRSTR were the heaviest ($P < 0.01$) entering the feedyard, followed by RSTR yearlings, and CALF-FED cattle had the lightest ($P < 0.01$) BW at the start of feeding. There were no differences ($P = 0.13$) due to backgrounding treatments for ADG of cattle in the feedyard; however, DELAY had greater ($P < 0.01$) ADG than IMPL. Cattle fed as calves had greater ($P < 0.01$) feed efficiency and less ($P < 0.01$) DMI per day while in the feedlot than did yearling cattle, which did not differ ($P \geq 0.05$). Studies have shown that cattle that have a greater percentage of body fat when entered into the feedlot are assumed to have less efficient rate of feed conversion and experience a lesser rate of gain in the finishing phase (NRC, 1996). However, McCurdy et al. (2010) reported that fatter calves at entry into the feedyard did not experience a reduction in ADG and actually had an improved finishing ADG and feed efficiency compared to the calves that were leaner at entry into the feedlot. Barham et al. (2012) also reported cattle entering the feedyard as calves to have a lesser ADG than cattle fed as yearlings. Cattle that received a delayed implant also experienced a greater feed efficiency and intake per day than cattle that were implanted prefinishing ($P \leq 0.05$). There was no effect of implant strategy on prefinishing or feedlot performance in Exp 1 of this study, indicating that the occurrence of cattle receiving a prefinishing implantation to under-perform cattle receiving their initial implant at the arrival to the feedyard to be variable. Barham et al. (2012) reported cattle that had been given an aggressive implantation regimen through backgrounding and finishing outperformed cattle that received a delayed implant.

Carcass Characteristics

Experiment 1

The effects of age entering the feedlot, prefinishing implantation, and prefinishing nutrient status on carcass characteristics for Exp. 1 are presented in Table 6. There were no backgrounding treatment x IMPL interactions ($P \geq 0.17$) for HCW, FT, REA, YG, marbling score, or percentage Choice. Unrestricted growth yearlings had a heavier ($P \leq 0.05$) HCW and dressing percentage than RSTR treatment, followed ($P \leq 0.05$) by CALF-FED. Smith and Lunt (2007) reported that cattle fed as calves often resulted in fatter, higher yield grade carcasses, but in many instances the quality grade has been equal to, or greater than, cattle fed as yearlings. There were no IMPL effects ($P = 0.46$) for HCW. There were no differences among treatments for fat thickness ($P > 0.05$). Unrestricted cattle had the greatest ($P < 0.02$) REA, followed by RSTR ($P < 0.01$) and CALF-FED had the smallest ($P < 0.01$) REA. There was no implant effect

($P = 0.41$) on REA. Restricted growth yearlings had the lowest YG followed by UNRSTR yearlings and CALF-FED had the greatest yield grade ($P < 0.01$). There was no implant effect ($P = 0.21$) on YG. Across all backgrounding treatments, cattle that received an implant prefinishing tended ($P = 0.06$) to have a lower marbling score and had lower percentage of cattle grading Choice ($P = 0.03$). This was expected, as previous studies show that implantation timing and strategy can have an impact on marbling, decreasing the quality grade and marbling score of the carcass (Duckett et al., 1999; Platter et al., 2003; Bruns et al., 2005). Calf-fed cattle had greater ($P = 0.02$) marbling score than UNRSTR and RSTR, which did not differ ($P > 0.05$). Studies show that feeding cattle as calves often results in fatter, lighter weight carcasses than cattle fed as yearlings, resulting in a greater quality grade (Smith and Lunt, 2007).

Experiment 2

The effects of age entering the feedlot, prefinishing implantation, and prefinishing nutrient status on carcass characteristics for Exp. 2 are presented in Table 6. There were no background x implant interactions ($P \geq 0.23$) for carcass characteristics in this experiment. Unrestricted growth yearlings had a greater ($P < 0.01$) HCW than did RSTR and CALF-FED groups, which did not differ ($P = 0.13$). Huffman et al. (1990) reported yearling cattle had greater HCW than cattle fed as calves when slaughtered at the same backfat thickness. Implantation had no effect ($P > 0.25$) on HCW, dressing percentage, backfat thickness, or REA. Cattle in the CALF-FED treatment had lower ($P < 0.01$) yield grades than RSTR or UNRSTR, which did not differ ($P = 0.62$). There was no effect of implantation on yield grade ($P = 0.22$). Cattle fed as calves had a greater back fat thickness than yearling cattle, which did not differ ($P = 0.03$) and RSTR and UNRSTR had a greater REA than did CALF-FED, but did not differ ($P = 0.50$). Neither backgrounding treatment nor implant strategy affected the percentage of cattle grading choice (P = 0.38) or marbling score (P = 0.32). Paisley et al. (1999) also reported that overall effect of implantation did not affect marbling score. Unrestricted yearling cattle had a greater carcass value than CALF-FED and RSTR cattle, which did not differ (P < 0.05). Previous studies evaluating economic comparisons indicate that calves undergoing a stocker phase and finished as yearlings are more economically efficient, deposit IMF at a greater rate, and have a greater rate of daily gain compared with calf-fed animals (Griffin et al., 2007; Barham et al., 2012). Barham et al. (2012) reported that implanting aggressively through a restricted growth backgrounding period and finishing increased REA and HCW and decreased YG, marbling score, and percentage choice. The differences between the current study and Barham et al. (2012) indicate that continued aggressive implantation through backgrounding and finishing will have greater impact on carcass characteristics than the moderate potency implants used in the current study through finishing.

Sensory Evaluation and Proximate Analysis

Experiment 1

The effects of age entering the feedlot, prefinishing implantation, and prefinishing nutrient status on proximate analysis and sensory evaluation for Exp. 1 are presented in Tables 7 and 8, respectively. There were no background x implant interactions ($P \geq 0.31$) for percent collagen, fat, moisture, or protein. There was no effect ($P \geq 0.23$) of background treatment or implantation on percent collagen or percent protein in beef; however, steaks from cattle that had been implanted prefinishing had less (P < 0.01) percent fat and greater (P < 0.01) percent moisture than DELAY. Unrestricted yearling cattle tended (P = 0.09) to have a greater percent moisture than CALF-FED or UNRSTR, which did not differ (P = 0.89).

There were no background or implant effects ($P \geq 0.10$) of initial juiciness, sustained juiciness, beef flavor or off flavor. Barham et al. (2012) also reported no differences in juiciness and beef flavor for steaks of cattle receiving different implant regimens. Panelists observed steaks from cattle that received an implant prefinishing to have less (respectively $P < 0.01$) initial and sustained tenderness; however there was no effect ($P \geq 0.23$) of background treatment on tenderness. Platter et al. (2003) found steaks from cattle that had been twice during their lifetime received reduced consumer score for tenderness, juiciness, flavor, and overall satisfaction. Samber et al. (1996) found that timing and administration strategy of implants have an impact on WBSF values. Cattle that received two doses of an estradiol implant initially and intermediately, followed by a terminal combination implant, or one dose of an estradiol implant followed by two doses of the combination implant resulted in no difference of WBSF compared with cattle that had not been implanted (Samber et al., 1996). Roeber et al. (2000) also reported that while implants have been shown to increase HCW and REA, implants can decrease the palatability of beef, causing a less than desirable eating experience for the consumer. Unrestricted growth yearling cattle had less ($P = 0.03$) flavor intensity than CALF-FED or UNRSTR cattle, which did not differ ($P = 0.06$). There were no background x implant interactions ($P = 0.19$) for any sensory characteristics. Cattle receiving a backgrounding implant had greater ($P < 0.03$) WBSF values than DELAY, and CALF-FED cattle had less ($P \leq 0.03$) WBSF value than RSTR or UNRSTR, which did not differ ($P = 0.60$)

Experiment 2

The effects of age entering the feedlot, prefinishing implantation, and prefinishing nutrient status on proximate analysis and sensory evaluation for Exp. 2 are presented in Tables 7 and 8, respectively. There was no effect ($P \geq 0.12$) of background treatment or implantation on percent collagen, fat, or moisture in beef, and no background x implantation interactions ($P \geq$ 0.17) for percent fat, moisture, or protein. Unrestricted growth yearlings had greater percentage ($P < 0.01$) of protein than RSTR, which had greater ($P < 0.01$) percentage of protein than CALF-FED cattle. There was a background x implant interaction ($P < 0.01$) for percent collagen in the beef; IMPL had more ($P <0.01$) collagen than DELAY across backgrounding treatments.

Panelists observed less ($P < 0.01$) initial and sustained juiciness in cattle that received a prefinishing implant compared with cattle that did not receive an implant until entry into the feedyard and CALF-FED cattle had the greatest ($P < 0.03$) amount of initial juiciness, followed by UNRSTR, and RSTR cattle having the least ($P < 0.01$). Beef from CALF-FED DELAY cattle were initially juicier ($P = 0.03$) than steaks from yearling cattle, regardless of implantation (background x implant, $P < 0.01$). Beef from UNRSTR cattle, regardless of implantation, had more sustained juiciness than RSTR yearlings (background x implant, $P < 0.05$) and steaks from DELAY RSTR had more sustained juiciness than beef from IMPL cattle ($P < 0.01$). Panelists observed that IMPL had less initial tenderness ($P < 0.01$), less sustained tenderness ($P = 0.03$), less flavor intensity ($P < 0.01$), and less beef flavor ($P < 0.01$) than beef from DELAY. Nichols et al. (2002) concluded that the current results available of the effect of implants on tenderness, if any, are limited. There was no effect of background on initial tenderness ($P = 0.28$), sustained tenderness ($P = 0.42$), flavor intensity ($P = 1.00$), or beef flavor ($P = 0.76$). Beef from IMPL was observed to have a less desirable mouth feel ($P < 0.01$) than beef from DELAY and beef from CALF-FED animals was observed to have the most desirable ($P \leq 0.05$) mouth feel, followed by UNRSTR yearlings, and RSTR yearlings having the least desirable mouth feel . There were no effects of background or implant on off-flavor of beef ($P = 0.35$ and $P = 0.95$, respectively) and there were no background x implant interactions for initial tenderness ($P =$

0.76), sustained tenderness (P = 0.95), flavor intensity (P = 0.14), or off-flavor of beef (P = 0.50). There was no effect of background (P = 0.68) on WBSF of steaks from these carcasses; however, steaks from IMPL cattle tended to have a greater (P = 0.06) WBSF value than steaks from DELAY cattle. Samber et al. (1996) reported that implantation timing and administration strategy have an impact on WBSF values and Roeber et al. (2000) found a reduction in palatability of steaks from cattle that had received implants.

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Table 1. Diets fed to cattle in drylot prior to finishing (CALF) or placing on winter annual pastures (UNRSTR and RSTR) during Experiments 1 and 2.

Feedstuff	Diet		
	60% Concentrate	70% Concentrate	80% Concentrate
	-------------------------% As Fed Basis--------------------------		
Mixed hay	39.9	30.0	20.0
Ground corn	27.5	32.6	37.7
SBH	26.9	31.7	36.6
CSM	2.1	2.1	2.1
Mineral Premix	1.2	1.2	1.2
Urea	0.9	0.9	0.9
Water	1.5	1.5	1.5
Nutrient Composition	---------------------------DM Basis-------------------------------		
NEm, mcal/kg	1.67	1.76	1.83
NEg, mcal/kg	1.06	1.12	1.20
CP, %	13.9	14.1	14.2

Table 2. Diets fed to cattle during finishing in Experiment 1.

	Diet	
Feedstuff	Grower	Finisher
	-------------------------% As Fed Basis--------------------------	
Corn silage	45.2	23.0
Sudangrass hay	10.0	-
Rolled corn	30.0	46.4
Rolled wheat	-	15.0
DDGS	12.5	10.0
Molasses	-	3.0
Supplement Premix[1]	2.3	2.6
Nutrient Composition	----------------------------------DM Basis-------------------------------	
NEm, mcal/kg	1.98	1.98
NEg, mcal/kg	1.25	1.26
CP, %	14.7	15.2

[1]Alfadale Stock Farms Finish Supplement designed to supply (As fed basis) 0.83 g/kg monensin, 0.25 g/kg Tylosin, 1% Molasses, 8.8% wheat midds, 7.5% sunflower meal, 47.3% limestone, 3.3% magnesium oxide, 8.0% potassium chloride, 12% salt, 10% urea, and 2.1% TM/vitamin premix (supplying Vitamins A and E, Cu as copper sulfate and carbohydrate complex, Mn as manganous oxide, Zn as zinc oxide and carbohydrate complex, EDDI, and Se).

Table 3. Diets fed to cattle during finishing in Experiment 2.

	Diet		
Feedstuff	Ration #1	Ration #2	Ration #3
	-------------------------% As Fed Basis--------------------------		
Whole Corn	34.0	45.0	54.0
DDGS	30.0	27.0	25.0
CSH	30.0	22.0	15.0
Westway Conditioner	4.0	4.0	4.0
Mixing Mineral	2.0	2.0	2.0
	--------------------------DM Basis------------------------------		
Nutrient Composition			
CP, %	14.4	20.0	15.5
NDF, %	33.4	29.4	27.1
ADF, %	13.6	8.5	7.4
NEm, mcal/kg	1.9	2.1	2.1
NEg, mcal/kg	1.3	1.4	1.4

Table 4. Effect of Age Entering the Feedlot, Prefinishing Implantation, and Prefinishing Nutrient Status on Performance during Backgrounding during Experiments 1 and 2.

Item	CALF-FED		RSTR		UNRSTR					
	DELAY[1]	IMPL[2]	DELAY	IMPL	DELAY	IMPL	SE	Background	Implant	Interaction
	-------------------------------Experiment 1-------------------------------									
Initial BW, kg	233	231	231	227	229	231	19.6	0.95	0.88	0.93
Shipping BW, kg	290[c]	294[c]	312[b]	345[b]	375[a]	400[a]	9.80	<0.01	<0.01	0.04
ADG, kg/d	1.35	1.45	0.49	0.68	0.86	1.01	0.08	<0.01	<0.01	0.48
Total Gain, kg	59.4[e]	64.0[e]	81.2[d]	114.3[c]	144.2[b]	169.2[a]	9.30	<0.01	<0.01	0.003
	-------------------------------Experiment 2-------------------------------									
Initial BW, kg	218	215	210	211	210	210	18.8	0.74	0.88	0.96
Shipping BW, kg	292	293	357	367	414	435	24.8	<0.01	0.20	0.65
ADG, kg/d	1.26	1.47	0.69	0.74	1.02	1.52	0.13	<0.01	<0.01	0.34
Total Gain, kg	52.2	61.7	123.4	132.9	182.8	206.8	15.4	<0.01	0.01	0.47

[1]DELAY- cattle received initial implant upon entry into feedlot. Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health)

[2]IMPL - Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health) at the beginning of preconditioning, at the start of grazing, at the initiation of feeding

Table 5. Effect of Age Entering the Feedlot, Prefinishing Implantation, and Prefinishing Nutrient Status on Performance during Finishing for Experiments 1 and 2.

Item	CALF-FED		RSTR		UNRSTR					
	DELAY[1]	IMPL[2]	DELAY	IMPL	DELAY	IMPL	SE	Background	Implant	Interaction
	Experiment 1									
Initial BW, kg	266	271	303	324	360	384	14.5	<0.01	0.02	0.35
Final BW, kg	528	533	542	552	583	589	27.5	0.01	0.50	0.98
ADG, kg/d	1.50	1.50	1.75	1.74	1.82	1.63	0.11	<0.01	0.15	0.18
Days on Feed	170	170	134	129	120	122	3.56	<0.01	0.75	0.56
Total Gain, kg	254.9	255.4	233.1	222.3	216.8	198.2	20.2	<0.01	0.24	0.60
	Experiment 2									
Initial BW, kg	267	272	304	325	360	385	6.7	<0.01	<0.01	0.29
Shipping BW, kg	529	534	545	554	584	590	12.2	<0.01	0.47	0.98
ADG, kg/d	1.50[c]	1.50[c]	1.75[ab]	1.74[ab]	1.83[a]	1.63[bc]	0.05	<0.01	0.10	0.10
Total Gain, kg	170	170	134	129	119	122	3.5	<0.01	0.74	0.53

[1]DELAY- cattle received initial implant upon entry into feedlot. Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health)

[2]IMPL - Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health) at the beginning of preconditioning, at the start of grazing, at the initiation of feeding

Table 6. Effect of Age Entering the Feedlot, Prefinishing Implantation, and Prefinishing Nutrient Status on Performance on Carcass Characteristics during Experiments 1 and 2.

Item	CALF-FED		RSTR		UNRSTR					
	DELAY[1]	IMPL[2]	DELAY	IMPL	DELAY	IMPL	SE	Background	Implant	Interaction
	------------------------------Experiment 1------------------------------									
HCW, kg	309	308	319	322	345	354	13.3	<0.01	0.46	0.70
Dressing, %	62.6[b]	61.7[b]	62.6[b]	62.1[bc]	63.1[b]	64.0[a]	0.30	0.01	0.61	0.09
Fat Thickness, cm	1.3	1.3	1.3	1.3	1.5	1.3	0.04	0.34	0.52	0.60
REA, cm^2	74.2	74.2	78.7	85.2	87.7	87.1	0.49	0.02	0.41	0.52
Yield Grade	3.9	3.8	3.2	2.7	3.1	3.0	0.20	0.01	0.21	0.59
Marbling Score	559	508	492	427	471	468	21.2	0.02	0.06	0.35
Quality Grade	Ave Ch	Ave Ch	Ch-	Ch-	Ch-	Ch-	6.5			
Choice, %	100	94.8	100	73.5	88.9	85.0	6.5	0.18	0.03	0.17
	------------------------------Experiment 2------------------------------									
HCW, kg	313	298	325	322	351	352	20.7	0.01	0.38	0.59
Dressing, %	60.8	60.6	63.2	64.1	64.5	63.7	0.61	<0.01	0.95	0.23

Fat Thickness, cm	1.3	1.1	1.6	1.7	1.8	1.6	0.05	0.03	0.25	0.37
REA, cm^2	81.4	79.7	87.7	86.7	84.8	86.9	0.31	0.03	0.90	0.56
Yield Grade	3.2	2.9	3.6	3.6	3.8	3.6	0.15	0.01	0.22	0.36
Marbling Score	471	455	436	449	482	480	23.4	0.32	0.92	0.83
Choice %	75.0	66.7	70.6	64.3	73.4	93.8	11.8	0.38	0.84	0.37

[1]DELAY- cattle received initial implant upon entry into feedlot. Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health)

[2]IMPL - Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health) at the beginning of preconditioning, at the start of grazing, at the initiation of feeding

Table 7. Effect of Age Entering the Feedlot, Prefinishing Implantation, and Prefinishing Nutrient Status on Performance on Proximate Analysis for Experiments 1 and 2.

Item	CALF-FED		RSTR		UNRSTR					
	DELAY[1]	IMPL[2]	DELAY	IMPL	DELAY	IMPL	SE	Background	Implant	Interaction
	Experiment 1									
% Collagen	1.6	1.5	1.7	1.7	1.7	1.7	0.27	0.88	0.48	0.56
% Fat	7.0	6.2	6.7	6.0	6.2	5.1	0.73	0.17	0.01	0.86
% Moisture	68.6	68.8	68.4	69.0	68.7	70.0	0.32	0.09	0.01	0.32
% Protein	22.9	23.4	23.4	23.4	23.5	23.6	0.21	0.22	0.24	0.31
	Experiment 2									
% Collagen	1.7^{ac}	1.6^{bc}	1.6^{ab}	1.8^{c}	1.6^{ab}	1.6^{ab}	0.36	0.57	0.49	<0.01
% Fat	5.0	4.1	5.7	6.4	5.6	4.7	1.74	0.20	0.36	0.17
% Moisture	70.4	70.9	68.9	69.0	69.2	70.0	0.66	0.12	0.12	0.52
% Protein	22.8	22.6	23.2	23.0	23.3	23.6	0.17	<0.01	0.96	0.25

[1]DELAY- cattle received initial implant upon entry into feedlot. Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health)

[2]IMPL - Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health) at the beginning of preconditioning, at the start of grazing, at the initiation of feeding

Table 8. Effect of Age Entering the Feedlot, Prefinishing Implantation, and Prefinishing Nutrient Status on Performance on Sensory Evaluation for Experiments 1 and 2.

Item	CALF-FED		RSTR		UNRSTR					
	DELAY[1]	IMPL[2]	DELAY	IMPL	DELAY	IMPL	SE	Background	Implant	Interaction
	---Experiment 1---									
Initial Juiciness	6.2	6.3	5.8	5.5	5.7	5.6	0.55	0.64	0.30	0.61
Sustainable Juic.	6.4	6.3	5.8	5.5	5.7	5.7	0.55	0.59	0.32	0.56
Init. Tenderness	6.5	6.4	5.9	5.4	6.0	5.5	0.43	0.28	<0.01	0.50
Sust. Tenderness	6.6	6.5	5.9	5.5	6.1	5.6	0.43	0.23	0.01	0.19
Initial Flavor	6.6	6.4	6.4	6.3	6.3	6.2	0.11	0.03	0.07	0.87
Beef Flavor	6.8	6.5	6.3	6.2	6.4	6.2	0.24	0.40	0.10	0.61
Off Flavor	1.1	1.1	1.2	1.2	1.3	1.2	0.26	0.75	0.47	0.98
WBSF	2.8	2.9	3.4	3.6	3.2	3.6	0.23	0.05	0.03	0.50
	---Experiment 2---									
Initial Juiciness	6.4^{a}	6.2^{a}	5.9^{ab}	5.0^{c}	5.8^{ab}	5.7^{b}	0.19	<0.01	<0.01	<0.001
Sustainable Juic.	6.0^{a}	5.8^{a}	5.8^{a}	4.9^{b}	5.7^{a}	5.7^{a}	0.20	0.02	<0.01	<0.01

Init. Tenderness	6.6	6.3	5.9	5.5	5.8	5.6	0.38	0.28	<0.01	0.76
Sust. Tenderness	6.3	6.1	5.9	5.6	5.8	5.6	0.33	0.42	0.03	0.95
Initial Flavor	6.4	6.2	6.6	6.1	6.4	6.3	0.17	1.00	<0.01	0.14
Beef Flavor	6.4^{a}	6.4^{a}	6.6^{a}	5.9^{b}	6.4^{a}	6.2^{ab}	0.22	0.76	<0.01	<0.01
Mouth Feel	6.0^{a}	5.8^{ab}	5.5^{bc}	4.7^{d}	5.6^{b}	5.2^{c}	0.18	<0.01	<0.01	0.08
WBSF	3.47	3.46	3.45	4.08	3.76	4.21	0.99	0.68	0.06	0.35

[1]DELAY- cattle received initial implant upon entry into feedlot. Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health)

[2]IMPL - Steers were implanted Synovex-S (Pfizer Animal Health, Madison, NJ) and heifers were implanted with Synovex-H (Pfizer Animal Health) at the beginning of preconditioning, at the start of grazing, at the initiation of feeding

CHAPTER IV

CONCLUSION

While some common practices of backgrounding include restricting intake of cattle while they are on pasture, these studies indicate that that may not be the best decision economically, if cattle are marketed on a quality-based grid. Producers often have the illusion that if retaining ownership through the feedyard, it can be beneficial to restrict gain during the prefinishing period so cattle can express compensatory gain during the finishing phase. However, this study shows that cattle never completely made up for the lost BW and had lighter carcasses, resulting in a decreased carcass value per head if nutrient restricted prior to the finishing phase. These results indicate that the best backgrounding option for producers who retain ownership would be the allow cattle to grow and gain at their maximum potential during prefinishing and continue to feed cattle to allow optimum gains during the finishing phase. Although we did not find RSTR yearlings to have less carcass quality in Experiment 2 from calf-fed and UNRSTR yearlings, there was a dramatic numerical decrease in carcass quality in Exp. 1.

These studies also indicate that there can be economic implications and effects on carcass quality if cattle are implanted during the preconditioning phase while on a negative plane of nutrition or while having limited nutrition resources. In experiments 1 and 2, the percentage of Choice carcasses in cattle that received an implant prefinishing while having restrictions on nutrition was numerically less, indicating that implanting cattle while feed resources are scarce during the growing phase would not be an acceptable management strategy to produce quality carcasses.

Finishing cattle as calves and choosing to forego backgrounding on pasture can be beneficial in terms of carcass quality and consumer acceptability of beef. Calf-fed calves in Experiment 2 proved to have the juiciest steaks, as well as the steaks with the most desirable mouth feel. Calf-fed cattle also had a greater percentage of carcasses grade Choice than the yearling treatments, indicating that cattle started on feed at a younger age tend to have better carcass quality. Although calf-fed cattle had a lower carcass value than yearlings on a high plane of nutrition prefinishing, they did not differ in value per head from yearlings on a low plane of nutrition. The reduction in carcass value for the calf-fed cattle is due to the lighter bodyweight at time of slaughter due to the younger age of cattle.