EFFECTS OF OPTAFLEXX FEEDING ON ANIMAL PERFORMANCE, CARCASS TRAITS, YIELDS OF CARCASS PRIMALS AND VALUE CUTS, AND MEAT TENDERNESS IN OVARIECTOMIZED HEIFERS

by

CLAYTON SEABORNE TALTON

(Under the Direction of T. Dean Pringle)

ABSTRACT

Forty-eight heifers, of predominantly British breeding, were used to investigate the effects of Ractopamine (RAC) supplementation and ovariectomization (OVX) on feedlot performance, carcass yield and quality traits, and subprimal and value-cut yields. Dressing percentage was higher ($P < 0.01$) in RAC-fed heifers than controls (CTL) and HCW, CCW, and REA tended ($P < 0.10$) to be increased by RAC feeding. Intact heifers had higher ($P < 0.01$) DP and larger ($P = 0.05$) REA and tended to have higher ($P = 0.09$) bone maturity scores and lower ($P = 0.09$) YG than OVX heifers. The ribeye roll, shoulder clod, and gooseneck round were heavier ($P < 0.05$) and the tenderloin and knuckle tended ($P < 0.10$) to be heavier in RAC-fed heifers compared to CTL. Conversely, OVX decreased ($P = 0.04$) the yield of the ribeye roll and tended ($P = 0.06$) to decrease the yields of the brisket and strip loin compared to INT heifers. The interaction of RAC supplementation and gender significantly affected the value cuts shoulder top and top blade weights. These value cut weights were higher ($P < 0.05$) with RAC feeding in INT heifers, while weights were similar in OVX heifers.

INDEX WORDS: Ractopamine, Ovariectomy, Heifers, Value Cuts

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DEDICATION

I would like to dedicate this work to my family. To my grandparents, Maxine Forehand and Andy and Lucy Talton; thank you for all the advice and lifelong lessons. You have been a great inspiration on our family through your unconditional love and guidance. To my mother, I don't think words could ever explain the impact you have had on my life. Thank you for all the love, guidance and inspiration you have given me. You have truly taught me the meaning of faith, perseverance, and generosity. To my father, thank you for all your support, education, love, and integrity. You have taught me not only what it means to be a man but also what it means to be a "Talton". Thank you both for your loving support as I have strived to achieve my lifelong goals. To my sister, thank you for all your support, advice and laughter. Your perseverance and kind heart has truly inspired me. Lastly, to my Uncle David, thank you for all of the memories and your love, support, and direction. I miss you. Thank you all for everything you have done for me, without your support and leadership, none of this would have been attainable. I love you all and I dedicate this work to you all.

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CHAPTER 1

INTRODUCTION

The beef industry operates on a high volume low margin, and it is challenged with meeting the ever-changing needs and expectations of consumers and regulations of governmental agencies, while maintaining profitability. Developments through research in cooperation with animal health companies have led to new products and methods that can benefit the consumer and industry. Development of feed additives that promote growth and maximize animal performance has become a topic of interest among producers and packers in order to maximize profit through increased weight gains with decreased economic input. Improving the efficiency of lean muscle growth is one way the industry can increase the return on it's investment by reducing costs of gain and positively impacting carcass composition and yields.

Ractopamine hydrochloride (RAC; Optaflexx®, Elanco Animal Health, Greenfield, IN) is a phenethanolamine with beta-adrenergic properties that increases lean meat production in many animal species. The U.S. Food and Drug Administration (FDA) recently approved the use of RAC in cattle finishing diets in June, 2003, and it has improved carcass lean growth in feedlot cattle by increasing carcass muscling (Schroeder et al., 2004). Feedlot steers fed RAC consistently showed increased ADG, gain:feed, carcass weight, and ribeye area (Schroeder et al., 2004). Ractopamine hydrochloride feeding appears to have its greatest impact on carcass muscling and in fact, carcass conformation scores are increased with RAC supplementation (Schroeder et al., 2004).

However, the response of feedlot heifers to RAC feeding has not been as predictable. In some cases, responses similar to those in steers have been reported; however, in others, little response has been noted (Schroeder et al., 2004; A.L. Schroeder, personal communication, 2 Aug 2005). Ovariectomization (OVX) is one way to potentially control the hormonal changes that could be responsible for variations in beef heifer's response to RAC supplementation. One caveat with OVX heifers is that they consistently have reduced gains and feed efficiency when compared with intact (INT) heifers; however, implanting with anabolic steroids appears to overcome the performance reductions noted with OVX (Kercher et al., 1958; Hortsman et al., 1982; Nygaard and Embry, 1966; Whetzal et al., 1966).

Furthermore, today's consumer demands convenient, palatable meat products from the marketplace. As a result of this desire, beef consumption has shifted from the consumption of roasts towards the purchase of quick and easy-to-prepare alternatives such as ground beef and steak products. In recent years, the value of the middle meats of the beef carcass has continued to increase while the value of the beef chuck and round have steadily declined. In response to these trends, the beef industry has conducted extensive research into adding value to cuts from the beef chuck and round (NCBA, 2002). These muscle profiling projects have focused on characterizing muscles of the round and chuck and identifying individual muscles within beef subprimals that could potentially be merchandised as value-added cuts. A number of new products have been developed from the shoulder clod, knuckle, and bottom round and have received marketing attention by the beef industry (NCBA, 2002). As the popularity of these new

beef value cuts increases, it will be important for the beef industry to understand the impact of various industry practices on the yields and palatability of these cuts.

CHAPTER 2

LITERATURE REVIEW

The use of β-adrenergic agonists (β-agonists) to improve feed efficiency and enhance carcass composition in livestock species has been well documented since the early 1980's. Ractopamine Hydrochloride (RAC) is a phenethanolamine with beta-adrenergic properties, which acts as a repartitioning agent and has been shown to enhance lean meat production in many animal species. Ractopamine has a structure similar to that of the catecholamine, epinephrine, a hormone, and norepinephrine, a neurotransmitter. These hormones are responsible for regulating smooth muscle contraction, blood pressure, cardiac rate, lipolysis, and glycogenolysis (Mersmann, 1989). Thus, beta-adrenergic agonists (β-AA) were initially used in human health for treating ashmatics, muscle atrophy, and obesity. As a result of further research in human health the increased use of β-AA in livestock species to improve carcass composition has become a well documented topic. Development of different types of β-AA led to production of RAC, which is the first form of a β-AA to be approved by the FDA for use in livestock species.

β-AA Mechanism of Action

Mammalian cells have beta-adrenergic receptors (βAR) embedded in the plasma membrane and these receptors have greater than 400 amino acids in a continuous chain. Seven hydrophobic transmembrane domains anchor a receptor in the plasma membrane and the ligand-binding site is in the center (Mersmann, 1998). Additionally, the receptors

have two extracellular recognition sites for the ligand and the correct G protein (Mersmann, 1998; Garrett and Grisham, 1999). Beta-adrenergic receptors were first classified as alpha (α) or beta (β) receptors by Ahlquist in 1948. Mersmann (1989) stated that "α-receptors are responsible for gut contraction and cerebral, skin and salivary gland arterioles, and β-receptors are responsible for heart rate, contractility, bronchodilation and stimulation of lipolysis."

Three βAR subtypes have been cloned from several species, including rats, rabbits, sheep, pigs, and cattle (Mills, 2002). Lands et al. (1967) were the first to characterize β-receptors into β1 and β2-receptors and Emorine et al. (1989) reported there to be a β3-receptor. The βAR subtypes share approximately 50% sequence homology and exhibit ligand selectivity such that the rank order of affinity for norepinephrine is β1AR > β2AR > β3AR (Mills, 2002). Epinephrine has a greater affinity for β2AR than does norepinephrine but binds the β1AR and β2AR with a similar affinity (Mills, 2002). Ractopamine has a binding affinity similar to epinephrine; however, ractopamine has a lower capacity to stimulate lipolysis than epinephrine, which is unrelated to its ability to bind to the receptor (Liu et al., 1989). The β1AR and β2AR are co-expressed in most tissues of the body but the β1:β2 varies according to tissue type. For example, in the rat, the heart is made up of mostly β1AR and lung and skeletal tissues are predominately β2AR (Mills, 2002). The β3AR has a limited pattern of expression and is found mostly in adipose tissue (Mills, 2002). In pigs, McNeel and Mersmann (1999) reported that subcutaneous adipose tissue has 73% β1, 20% β2, and 7% β3-receptors and that skeletal muscle has approximately 60% β1, 39% β2, and <1% β3-receptors. Additionally, the pig heart contained 72% β1, 28% β2, and .25% β3-receptors.

The three subtypes also differ in regulation by phosphorylation, gene expression and G-protein selectivity (Strosberg, 1996). The G-proteins multiple subunits that have been identified and bind βAR have varying affinity and show differential tissue expression. These differences lead to a varying range in the response to a given ligand (Mills, 2002). Additionally, sequence homology for the subtypes is high across species; however, Mills (2002) states "One cannot assume that all the pharmacological properties of a given subtype will be the same across species." The ability of a ligand to express high or low affinity for a βAR, and to signal through G-proteins, is highly dependent on the amino acid sequence, which differs across species (Mills, 2002). Thus, the effects of ractopamine can vary between species.

The β-AA primary signal comprises of a β-AA that binds to a βAR and activates a Gs-protein. In turn, the α-subunit of the Gs-protein activates adenylate cyclase, which is the enzyme that synthesizes cyclic adenine 3', 5' – monophosphate (cAMP). Cyclic AMP binds to the regulatory subunit of the enzyme protein kinase to phosphorylate and activate proteins such as hormone sensitive lipase and glycogen phosphorylase (Buttery and Dawson, 1987; Mersmann, 1989 and 1998; Murray et al., 1996). Phosphorylation of glycogen synthase and acetyl CoA carboxylase by protein kinase is inhibitory, meaning lipolysis and glycogenolysis are stimulated and glycogen and fatty acid biosynthesis are inhibited under conditions where cAMP is elevated (Mills et al, 1990; Mersmann, 1998; Garrett and Grisham, 1999). The receptor is then phosphorylated and removed from the cell surface (Ding et al., 2000). The cell can become less sensitive to stimulation and the effect of β-AA is attenuated if the rate of receptor exposure to β-AA is greater than the rate of receptor replacement (Spurlock et al., 1994).

The secondary signal of β-AA consists of the G-protein. Adenylate cyclase cannot be activated in the absence of the G-protein (Rodbell, 1980). Two classifications of G proteins exist: Gs and Gi. The Gs protein stimulates adenylyl cyclase and the Gi protein inhibits adenylate cyclase. Both of these proteins are capable of binding with guanine triphosphate (GTP). Three subunits (α, β, and γ) exist in both proteins. The α-subunit dissociates when GTP binds to the G-proteins and binds with adenylate cyclase, thus eliciting a response (Garrett and Grisham, 1999). The G protein has intrinsic guanine triphosphatase (GTPase) activity. When GTPase hydolyses GTP to guanine diphosphate (GDP), the α-subunit reassociates with the β and γ-subunits (Rodbell, 1980; Garrett and Grisham, 1999).

Adipose Tissue Metabolism

Fat accretion is a balance between the degradation and synthesis of lipids (Buttery and Dawson, 1987). Initial studies of βAR ligands showed decreases in adipose tissue accretion, which led to a number of ligands being studied for their antiobesity properties. In lipogenesis, fatty acids are synthesized using acetyl and malonyl groups. Acetyl coenzyme A (acetyl CoA) is derived from glucose via a series of reactions in the glycolytic pathway and is then converted to malonyl CoA by the enzyme acetyl CoA carboxylase. Acetyl and malonyl groups then undergo fatty acid synthesis where more carbon groups are added to form fatty acids such as palmitate (Garrett and Grisham, 1999). "Activation of protein kinase A is also antilipogenic due to phosphorylation and inactivation of glucose transport and acetyl CoA carboxylase and reduced expression of lipogenic genes" (Mills, 2002). Phosphorylation inhibits lipogenesis as acetyl CoA

carboxylase is inactive when phosphorylated by protein kinase and cAMP (Garrett and Grisham, 1999).

In lipolysis, triacylglycerols are broken down into free fatty acids that are released from adipose tissue into circulation. Fatty acids are stored in adipose tissue as triglycerides and are mobilized by epinephrine, glucagons, and adrenocorticotropic hormone, which activate protein kinase to phosphorylate hormone sensitive lipase (Garrett and Grisham, 1999). Mills (2002) states "activation of the βAR in adipose tissue and increased protein kinase A activity leads to the activation and translocation of hormone-sensitive lipase followed by triglyceride hydrolysis." The free fatty acids formed from this hydrolysis then undergo β-oxidation to form acetyl CoA, which is then fed back into the Citric Acid Cycle to produce ATP for energy (Garrett and Grisham, 1999).

Lipogenesis is more sensitive to ractopamine than is lypolysis (Mills and Liu, 1990). Mills et al. (1990) suggests that lipid biosynthesis is reduced by as much as 40% in pigs supplemented with RAC. However, other research suggests that RAC has no effect on lipogenesis (Dunshea, 1993; Liu et al., 1994). Additionally, Liu and Mills (1989) reported an increase in lipolysis in pigs supplemented with RAC. In contrast, several researchers have reported no change in the mobilization or oxidation of lipids from adipose tissue due to RAC (Mills et al., 1990; Mills and Liu, 1990; Dunshea, 1993; Liu et al., 1994).

Ractopamine increases the levels of cAMP to allow protein kinase mediated phoshorylation of enzymes (Mills et al., 1990). Cyclic AMP is sensitive to the presence of intracellular adenosine, thus protein kinase cannot be phosphorylated and then

metabolic enzymes responsible for lipid metabolism cannot be activated or inhibited, preventing the ractopamine action (Mills et al., 1990). Additionally, insulin is responsible for glucose utilization and promotion of free fatty acids and glycogen synthesis and it has been reported by Mills and Liu (1990) to antagonize the action of ractopamine by decreasing the cell sensitivity in adipocytes. Peterla and Scanes (1990) reported insulin decreased the lypolysis stimulated by β-AA and that it completely blocked the antilipogenic effects of ractopamine. Additionally, they reported that RAC stimulated in vitro lipolysis, indicated by an increased release of fatty acids or glycerol, and inhibited the basal rate of fatty acid biosynthesis.

Protein Metabolism

Most evidence of the increase in protein accretion due to β-AA points to the βAR as mediating the growth response. The primary effect of β-AA is to cause fiber hypertrophy without an associated increase in DNA; thus, indicating that protein synthesis, degradation, or both are affected (Mills, 2002). Postnatal muscle growth is hypertrophic and the mode of action of β-AA has been unclear as to whether increased accretion was due to decreased degradation or increased synthesis. These compounds have been reported to have effects on both degradation (Sainz et al., 1993a) and synthesis (Helferich et al., 1988). In most cases, the greatest effect has been on protein degradation due to decreased calpain system activity (Pringle et al., 1993; Sainz et al, 1993a). The endogenous cysteine proteinases, μ- and m-calpain and their inhibitor, calpastatin, have been studied during β-AA treatment. Reports indicate that activity of calpastatin, the endogenous inhibitor of μ and m-calpain, is increased with treatment (Koohmaraie et al., 1991). In agreement, Pringle et al. (1993) reported that calpain activity was significantly

lower and calpastatin activity was 73% higher in β-AA treated lambs. Garber et al. (1976) determined that epinephrine decreased the release of amino acids from muscle and the effect is demonstrated by βAR and the adenylate cyclase system, accounting for the inhibition of muscle protein degradation.

Additionally, protein synthesis has been shown to account for increased protein accretion, as Helferich et al. (1988) reported actin protein synthesis was increased by 50% with RAC supplementation in pigs. Alternatively, Anderson et al. (1989) suggested there to be a decrease in protein degradation followed by an increase in protein synthesis due to β-AA treatment. However, Bergen et al. (1989) determined increased protein accretion was due to increases in both synthesis and degradation with RAC supplementation.

Regardless of the differences in data, it can be concluded that any response to β-AA treatment is due primarily to hypertrophy and not hyperplasia. This theory is demonstrated by the ratio of protein to DNA, an indicator of cell mass or size. Bergen et al. (1989) reported a decrease in the DNA content of pig muscle after supplementation of RAC. This is in agreement with data reported by Pringle et al. (1993), in which the protein:DNA ratio was greater in β-AA treated animals, suggesting that β-AA muscle growth is hypertrophic.

β-AA Effects on Live Animal Performance and Carcass Composition

Ractopmanine feeding has been shown to improve average daily gain (ADG), feed to gain ratio (F/G), decrease carcass fat, increase carcass lean, and improve dressing percentage and hot carcass weight (HCW). In the livestock industry, producers are paid on a value-based pricing system where carcass leanness and fat are the primary

contributors to this system. All of the aforementioned improvements play a considerable role in increasing profits for producers. Schroeder et al. (2004) reported increased ADG, F/G and HCW in cattle treated with RAC. Additionally, in pigs, researchers have reported increases in ADG (Watkins et al., 1990; Stites et al., 1991) and feed intake (Aalhus et al., 1990; Watkins et al., 1990). However, there are many factors that could be responsible for observed differences in research experiments, including: protein supplementation, level of ractopamine, age and starting weight. Dressing percentage increased in response to supplementation of β-AA (Watkins et. al., 1990; Stites et al., 1991; Pringle et al., 1993; Armstrong et al., 2004; Schroeder et al., 2004). This would indicate an increase in edible carcass tissue and not an increase in visceral mass.

Several studies indicate that feeding RAC to pigs decreases average backfat (Hancock et al., 1987; Watkins et al., 1990; Yen et al., 1990). Additionally, it has been reported that tenth rib fat is more affected in pigs than other fat depots (Anderson et al., 1989; Watkins et al., 1989; Watkins et al., 1990; Yen et al., 1990). However, other reports indicated that tenth rib fat was unaffected by RAC (Stites et al. 1991; Sainz et al., 1993b; Armstrong et al., 2004). Schroeder et al. (2004) reported no effects on 12^{th} rib backfat in feedlot steers or heifers supplemented with RAC. Additionally, they reported carcass fat percentage numerically decreased for all levels of RAC, with steers fed 200 mg/hd/d being significantly reduced and those fed 300 mg/hd/d tending to be reduced. In heifers, carcass fat percentage numerically decreased across all RAC treatments, while the 300 mg/hd/d treatment group had a significantly reduced fat percentage compared to controls.

Many researchers have reported changes in carcass lean due to the effects of feeding RAC or any other β-AA. In many studies with pigs, the loin muscle area increased with supplementation of RAC (Anderson et al., 1987; Watkins et al., 1989; Watkins et al., 1990; Yen et al., 1990; Stites et al., 1991, Armstrong et al., 2004; Schroeder et al., 2004). Additionally, there are reports of increased muscle score in pigs (Watkins et al., 1990) and increased conformation scores in cattle (Schroeder et al., 2004) when supplementing RAC in finishing diets.

Weight and yield of trimmed and untrimmed carcass cuts and muscles are another way to express changes in composition due to RAC supplementation. Most studies report weights of untrimmed cuts are not significantly affected by RAC supplementation when compared to control animals (Yen et al., 1990; Stites et al., 1991; Utttaro et al., 1993; Crome et al., 1996). However, Stites et al. (1991) and Crome et al. (1996) reported an increase in the untrimmed weight of the ham and loin. Additionally, Crome et al. (1996) reported an increase in the weight of the picnic and boston butt. In pigs, the weights of the trimmed primal cuts of ham, loin, belly, boston butt, and picnic increased with supplementation of RAC (Aalhus et al., 1990; Yen et al., 1990; Uttaro et al., 1993; Crome et al., 1996). Additionally, Crome et al. (1996) noted an increase in weight of boneless, trimmed retail cuts from the tenderloin, boston butt, picnic, ham, and loin due to supplementation of RAC. Furthermore, the ham was dissected and separated into individual muscles and the individual weights of the inside, outside, and knuckles were increased with RAC supplementation. In addition, when trimmed primals were expressed as a percentage of the carcass side weight they were fabricated from, Stites et al. (1991) and Crome et al. (1996) noted an increased percentage in the ham and loin.

β-AA Effects on Carcass Quality

Meat color is an important characteristic and is the single most important quality factor because it greatly affects point of purchase for the consumer. Color in fresh meat is typically measured using colorimeters or by using subjective color standards adopted by the meats industry. Colorimeters use three values, L*, a*, and b*, which measure light reflectance. L* values measure lightness, a* values measure red to green, and b* values measure yellow to blue. Subjective color standards in pork range from 1 to 5 scale and are adopted by the National Pork Producers Council (NPPC). Standards in beef were analyzed on a 1 to 7 scale with 1 being least acceptable (Schroeder et al., 2004). Uttaro et al. (1993) reported no changes in L* values between control pigs and pigs fed a diet of 20 ppm of RAC. There were lower a* and b* values reported in both the loin and fresh ham of RAC fed pigs, which suggests less red and less yellow in both cuts. Chrome et al. (1996) reported no differences in subjective lean color scores in one group of lower weight pigs with increased RAC concentration. However, subjective lean color scores were lower in RAC supplemented pigs of the higher carcass weight group. Additionally, Stoller et al. (2002) reported no differences in L* values or subjective color scores in the measured loin eye. However, a* and b* values were lower in treated pigs compared to controls. Shroeder et al. (2004) reported no changes in muscle color of RAC-treated steers (0, 100, 200, 300 mg/hd/d) measured on a subjective color score scale. However, slight changes were reported in treated heifers (0,100, 200, 300 mg/hd/d) as a darker color score was observed with RAC supplementation.

Intramuscular fat (IMF) or marbling is associated with the eating quality of meat by many researchers. The amount of IMF can be measured subjectively, by using

marbling scores for pork developed by NPPC and scores for cattle developed by the United States Department of Agriculture (USDA), or objectively by chemical analysis of the muscle tissue. Watkins et al. (1990) reported changes in marbling scores in pigs treated with RAC. However, these changes were only 0.4 units of a score higher than the controls on a scale from 1 to 5. Crome et al. (1996) supplemented pigs with 0, 10, and 20 ppm RAC and found no differences between control and RAC pigs graded on a 3-point scale. Stites et al. (1991) fed RAC at four different treatment levels (0, 5, 10 and 20 ppm) resulting in no changes in IMF of the *longissimus dorsi* in carcasses that were treated versus those that were fed control diets. Additionally, using the same four treatment levels, Stites et al. (1994) reported numerically higher values for fat percentage of the longissimus in treated hogs. In cattle, Schoeder et al. (2004) reported no differences in marbling score or quality grade between the control and treated heifers and steers. There were no differences in IMF observed across the different levels of RAC supplemented. Collectively, research gathered on the effects of RAC on marbling has shown no considerable changes in amount of marbling in either cattle or pigs.

Tenderness is a quality factor of great concern to most consumers, because it relates to palatability. "The increased rate of protein synthesis and lipolysis in pigs fed RAC has resulted in some concern about the toughness of meat that is produced" (Uttaro et al. 1993). Tenderness is measured in both subjective sensory panels and objectively by Warner-Bratzler shear force (WBS) values. Uttaro et al. (1993) reported significant differences for WBS of pigs fed a control diet and a 20 ppm RAC treated diet. Values taken from the loin were higher for treated pigs; however, values from the ham were not significantly different from controls. Aalhus et al. (1990) used four different

concentrations of RAC (0, 5, 10 and 20 ppm) and reported that WBS force values in the loin increased 13.7 %, 16.2% and 15.3% as concentration of RAC increased from 0 to 20 ppm. The average increase of 15% represents close to one kg increase in shear force, which may result in consumers rating the product as being tough (Aalhus et al. 1990). Stites et al. (1994) reported no changes in values of fresh loin sensory tenderness and fresh loin WBS force values between control and RAC-treated groups.

Schroeder et al. (2004) reported all treatments in cattle of 0, 100, 200, and 300 mg/hd/day were considered acceptably tender and were well within ranges found in today's beef carcass population. Although WBS force values for the 300 mg/hd/d group were higher than that of the controls. These values were not different between the control and the 100 mg/hd/d and 200 mg/hd/d RAC diets. Schroeder et al. (2004) measured sensory panel tenderness values on a scale from 0 (not tender) to 150 (very tender). No differences were reported for the 0 mg/hd/d, 100 mg/hd/d and 200 mg/hd/d groups. However, the 300 mg/hd/d treatment group were rated significantly less tender than the other treatment groups. Tenderness values for both pigs and cattle taken with WBS force and sensory panels have shown increased toughness in higher concentrations for RAC supplementation. However, all the values reported were within acceptable levels of tenderness. These slight decreases in tenderness could be due to increases in muscle protein synthesis resulting in muscle hypertrophy and larger muscle fibers.

Ovariectomization

Feedlot steers fed RAC consistently have shown increased ADG, gain:feed, carcass weight, and ribeye area. However, the response of feedlot heifers to RAC feeding has not been as predictable. In some cases, responses similar to those in steers

have been reported; however, in others little, if any, response has been noted. Ovariectomization (OVX) is one way to potentially control the hormonal changes which could be responsible for variations in beef heifer's response to RAC supplementation.

Beef heifers are generally discriminated against in the livestock feeding industry, with steers being the preferred feedlot animal. Heifers generally produce fatter carcasses and are less efficient in feed conversion because of riding behaviors and decreased feed intake during estrous cycles (Klindt and Crouse, 1990). Ovariectomy or spaying has been used as a means of controlling behavior related to estrual activity observed in heifers confined to the feedlot. However, ovariectomizing heifers has the negative effect of removing the gonadal steroids (Klindt and Crouse, 1990), and the practice results in decrease gains and feed efficiency compared with intact heifers (Kercher et al., 1958; Horstman et al., 1982). In bulls and heifers, testes and ovaries secrete steroids that influence the performance traits. To reach maximum growth potential, Heitzman (1976) suggests that androgens and estrogens are necessary. Crouse et al. (1987) suggested that maintaining a natural hormone balance in cattle optimizes maximum growth. Concentrations of steroids in blood that result in maximum growth rates correspond to a combination of the androgen level in bulls and the estrogen level in heifers (Crouse et al., 1987). In current cattle operations in the United States, bulls are castrated and implanted with a combination of estrogens and androgens and androgenic preparations are used in heifers (Crouse et al., 1987). They speculated that heifers the manipulation of endogenous and exogenous anabolic hormones in heifers that are directly related to tissue growth could result in growth rates and efficiency that are comparable to intact and castrated males. To minimize the negative effects of ovariectomization, researchers have

reversed suppression of weight gain and feed efficiency by concurrent administration of anabolic steroids in heifers (Adams et al., 1990).

Ovariectomy Effects on Live Performance

The effects of ovariectomization on heifer performance reported in the literature are varied. Whether heifers are implanted with certain preparations of hormones or are ovariectomized before puberty can influence reported findings. Vestergaard et al. (1995) reported feed intake, ADG and gain:feed ratio were all unaffected in heifers treated with recombinant bovine growth hormone and ovariectomized between 73 and 83 d of age. Addtitionally, Crouse et al. (1987) reported no differences in ADG between control and OVX heifers implanted with trenbolone acetate at 56 d intervals during the treatment period. Heifers used in that study were assigned to treatments before reaching puberty, and they were late maturing and intermediate maturing crossbred heifers that weighed about 200 kg at the initiation of the study. Jeong et al. (1999) reported no differences in ADG between control and ovariectomized heifers that were not implanted and were approximately 24 months old at slaughter. Furthermore, Klindt and Crouse (1990) found no difference in rate or efficiency of gain for OVX and control heifers. In that study, heifers were not implanted and ovariectomies were performed at 6 months of age. These findings are also in agreement with Hamernik et al. (1985) Grotelueschen et al. (1988), Adams et al. (1990) and Field et al. (1996) who reported ovariectomy did not significantly influence the growth rate or efficiency of heifers.

Contrary to these findings, Dinnusson et al. (1950), Kercher et al. (1960), Nygaard and Embry (1966) and Horstman et al. (1982) indicated that ovariectomy had an adverse influence on rate and efficiency of growth. The explanation of this difference is

not apparent. Klindt and Crouse (1990) speculated that much of the difference was related to age and management of heifers as they state younger slaughter age combined with their being of a breed that is later maturing may have contributed to some of the discrepancies between the present results and those reported previously. Additionally, Hamernik et al. (1985) speculated that shorter finishing periods or difference in age at time of ovariectomy compared with studies by Dinnuson et al. (1950) and Hortsman et al. (1982) could explain why ADG was similar between treatment groups. Results reported by Field et al. (1996) are in agreement with Klindt and Crouse (1990), however, Field et al. (1996) performed ovariectomies at 1 yr of age and harvested heifers at 31, 33 and 35 mo of age. Klindt and Crouse (1990) and Grotelueschen (1988) both used heifers of continental breeding, which is different than that of earlier studies whose findings are not in agreement.

Ovariectomy Effects on Carcass Composition

Ovariectomy had no effect on the hot carcass weight of heifers in several experiments (Hamernik et al., 1985; Adams et al., 1990; Klindt and Crouse, 1990; Vestergaard et al., 1995; Field et al., 1996; Choat et al., 2006). Adams et al. (1990) reported lower dressing percentages in heifers that were ovariectomized. Contrary to these findings, Vestergaard et al. (1995) and Field et al. (1996) reported higher dressing percentage in OVX heifers compared to intact and Hamernik et al. (1985) and Klindt and Crouse (1990) reported no differences. Field et al. (1996) suggests differences in dressing percent are related to the lack of reproductive tract development in OVX heifers. Fat over the rib or fat at the 12^{th} rib interface was unchanged with OVX treatment compared with INT heifers (Crouse et al., 1987; Hamernik et al., 1985; Adams et al.,

1990; Klindt and Crouse, 1990; and Field et al., 1996). However, Vestergaard et al. (1995) reported increased backfat in OVX heifers compared with INT heifers.

Ribeye area was not affected by OVX of heifers (Hamernik et al., 1985; Adams et al., 1990; Klindt and Crouse, 1990; and Vestergaard et al., 1995); however, both Crouse et al. (1985) and Field et al. (1996) report smaller REA in OVX heifers compared with INT heifers. Kidney, pelvic and heart fat were not different in OVX heifers and INT heifers (Hamernik et al., 1985; Crouse et al., 1987; Klindt and Crouse, 1990; Vestergaard et al., 1995). In contrast, Field et al. (1996) reported kidney, pelvic and heart fat to increase with OVX. Hamernik et al. (1985) and Adams et al. (1990) reported similar yield grades in OVX and INT heifers.

Ovariectomy Effects on Carcass Quality

Marbling or intramuscular fat was not different in OVX and INT heifers (Hamernik et al., 1985; Crouse et al., 1987; Vestergaard et al., 1995; Field et al., 1996). However, Adams et al. (1990) reported increased marbling in OVX heifers. Field et al. (1990) reported similar lean maturity in OVX and INT heifers, but Klindt and Crouse (1990) reported decreased lean maturity in OVX heifers. Bone maturity and overall maturity both decreased in OVX heifers compared with INT heifers (Klindt and Crouse, 1990; Field et al., 1996). Klindt and Crouse (1990) speculate that estrogens produced by the ovaries may hasten skeletal and overall maturation. Tenderness measured by Warner-Bratzler shear force is reported to be unchanged with ovariectomization (Crouse et al., 1987; Adams et al., 1990).

Value Cut Yields

Currently, there is no research available on the effects of RAC or ovariectomy on the Beef Value Cuts yields as either a weight basis or percentage basis from the carcass or primal. However, projects have been conducted to determine approximate yields of these cuts from beef carcasses. Muscle profiling projects have reported much of the data available on these new cuts.

The shoulder clod contains and can be fabricated into the shoulder center (*triceps brachii* long head), shoulder top (*triceps brachii* lateral head), and top blade (*infraspinatus*). When derived from carcasses weighing 317-362 kg, the *infraspinatus* is reported to weigh approximately 1.74 kg and be 3.01 percent of the total chuck weight when denuded. The *triceps brachii* weighs approximately 3.12 kg and 5.40 percent of the primal chuck weight when denuded. When derived from carcasses weighing 385-408 kg the *infraspinatus* is reported to approximately weigh 2.07 kg and be 3.02 percent of the primal chuck weight when denuded. The *triceps brachii* weighs approximately 3.78 kg and 5.51 percent of the primal chuck weight when denuded. Weights for the *tricep brachii* include both the lateral and long head (NCBA, 2000).

The knuckle contains and can be fabricated into the tip center (*rectus femoris*) and the tip side (*vastus lateralis*). When derived from carcasses weighing 317-362 kg, the *rectus femoris* is reported to weigh approximately 1.24 kg and be 3.24 percent of the total round weight when denuded. The *vastus lateralis* weighs approximately 1.65 kg and 4.26 percent of the primal chuck weight when denuded. When derived from carcasses weighing 385-408 kg the *rectus femoris* is reported to approximately weigh 1.51 kg and be 3.24 percent of the round weight when denuded. The *vastus lateralis* weighs

approximately 1.92 kg and 4.13 percent of the primal chuck weight when denuded (NCBA, 2000).

The gooseneck round contains and can be fabricated into the bottom round trimmed flat (*biceps femoris*) and the bottom round ischiatic head (*biceps femoris* ischiatic head). When derived from carcasses weighing 317-362 kg, the *biceps femoris* is reported to weigh approximately 5.19 kg and be 13.48 percent of the total round weight when denuded. When derived from carcasses weighing 385-408 kg the *biceps femoris* is reported to approximately weigh 6.01 kg and be 12.94 percent of the round weight when denuded. These weights and percents include both the *biceps femoris* and *biceps femoris* ischiatic head (NCBA, 2000).

Slice Shear Force and Tenderness

Warner-Bratzler shear (WBS) force is typically the method used for evaluation of tenderness in meat animals. Evaluation is comprised of removal of six 1.27-cm diameter cores from each steak measured and is considered highly repeatable when measurement protocols are executed properly (Wheeler et al., 1994, 1996, 1997; Shackelford et al., 1999). However, Wheeler et al. (1994, 1996, 1997) identified several sources of error in shear force assessment within and among institutions. Thus, Shackelford et al. (1999) developed a simplified technique for measuring longissimus shear force called slice shear force. The slice shear method involves removing one slice, 1 cm thick and 5 cm long, which is parallel to the muscle fiber orientation. Also, slice shear uses a flat blade, whereas WBS uses a v-shaped blade. The slice shear blade is the same thickness, 1.016 mm, and has a half round degree of bevel on the shearing edge (Shackelford et al., 1999).

Shackelford et al. (1999) conducted three experiments to test the accuracy of the slice shear method using beef longissimus muscle. In experiment 1, Shackelford et al. (1999) found when slice shear force measurement was conducted immediately after cooking using belt grill cookery for the slice shear force steak, the tenderness ratings between slice shear force and trained sensory panel evaluation did not differ. In experiment 2, Shackelford et al. (1999) found slice shear force to be more strongly correlated with sensory panel tenderness ratings than WBS force. Furthermore, in experiment 3, Shackelford et al. (1999) evaluated the repeatability (.91) of slice shear force over a broad range of tenderness. Shackelford et al. (1999) concluded that slice shear force is a more rapid, more accurate, and technically less difficult than the Warner-Bratzler shear force method. Currently, there is no reported data or methods on slice shear force of beef value cuts or other various carcass muscles. However, S.D. Shackelford (personal communication, July 27, 2006) correlated slice shear values to WBS values for the longissimus muscle by using the equation, longissimus WBS = (0.106283 * longissimus slice shear force) + 2.27. This equation allows slice shear values to be understood and related to those values seen in WBS tests, as wells as relate these values to consumer thresholds for tenderness stated by Miller et al. (2001).

Warner-Bratzler shear force has been reported on the beef value cuts; however, slice shear values have not been reported nor have WBS values been correlated and reported on expected slice shear values. From the chuck, the top blade (*infraspinatus)* has measured at 6.21 lbs for moist heat cookery and 7.59 lbs for dry, the *triceps brachii* has measured at 9.78 lbs and 9.29 lbs for moist heat and dry heat cookery, respectively. From the knuckle, the tip center (*rectus femoris)* has measured at 8.39 lbs for moist heat

and 8.04 lbs for dry heat cookery, the tip side (*vastus lateralis*) has measured at 10.62 lbs for moist heat cookery and 11.63 lbs for dry. From the gooseneck round, the *biceps femoris* has measured at 10.62 lbs for moist heat and 9.93 lbs for dry heat cookery.

Conclusion

Muscle growth, fat deposition and product quality are of great concern to the red meats industry. Past research has shown the positive effects of RAC supplementation on carcass composition and consequently increased profit potential. Many forms of β-AA are available, but RAC is the only β-AA approved by the FDA. It is considered to be a safe and reliable source of β-AA for composition improvements in both cattle and swine. While other forms of β-AA provide many of the same effects as RAC, many of them have proven unsafe for the animal or the consumer, and they can have various adverse effects on carcass quality. Ractopamine research varies between studies: however, it generally increases the hypertrophy of muscle fibers and decreases fat deposition, which are positive effects on carcass quality. Additionally, tissue receptors are different within tissues and between species. More research is needed in both cattle and swine to determine the effects of varying concentrations of RAC on animal growth and carcass composition, assuming these compounds are approved and label limits are followed. In addition the effects of the RAC-induced increase in lean growth on protein and energy requirements of livestock need to be determined. Additionally, there are great differences in percentages of receptors within a tissue and between species, more research on the receptors would be beneficial to determine where RAC has its greatest effect.

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Chapter 3

EFFECTS OF OPTAFLEXX FEEDING AND OVARIECTOMY ON ANIMAL PERFORMANCE, CARCASS TRAITS, YIELDS OF CARCASS PRIMALS AND VALUE CUTS, AND MEAT TENDERNESS IN HEIFERS [1]

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[1] Talton, C.S., J.S. Shook, G.M. Hill, T.D. Pringle, C. Kerth, M. Pence To be submitted to Journal of Animal Science

Abstract

Forty-eight heifers, of predominantly British breeding, were used in this study and fed at the Coastal Plains Experiment Station in Tifton, GA. Heifers were sorted into two feeding groups (n = 24 heifers per group). Within a feeding group and gender, the heifers were randomly assigned to pens (n = 4 pens with 6 heifers per pen) for feeding. Half of the pens were randomly selected for ovariectomization (OVX; n = 12 heifers per feeding group). Prior to initiation of feeding, OVX were performed by a veterinarian. After an appropriate recovering period (approximately 3 weeks), all heifers were implanted with Component TE – IH and weighed to begin the feeding period (day 1). Cattle were fed concentrate and corn silage finishing diet in a TMR for 131 d for group 1 and 145 d for group 2. Within a gender subclass (OVX vs. intact; INT), half of the pens were randomly selected to receive a ractopamine (RAC) supplementation of .41 mg/kg of BW top dressed as a Type B supplement using corn as a carrier during the last 31 d of feeding. Cattle not receiving RAC were fed additional ground corn, top dressed as an equal percentage of BW as compared to pens receiving RAC during the last 31 d of feeding.

Upon completion of the feeding period, a feeding group (n = 24) was transported to Athens, GA (n=12) at the UGA Meat Science and Technology Center and Auburn, AL (n=12) at the Auburn University Lambert Powell Meats Lab and harvested using standard industry procedures. Two weeks later the second feeding group was shipped to the respective abattoirs. Heart, lung, liver, spleen and kidney weights were collected at harvest. Shrunk live weight and hot carcass weight were recorded. Following a 24-h chill, cold carcass weight was recorded and both sides of each carcass were ribbed between the 12^{th} and 13^{th} ribs and USDA yield and quality grade information were

collected from both sides and averaged for each carcass. In addition, longissimus pH and Hunter L*, a*, and b* reflectance values were measured.

Left sides of carcasses were weighed to determine the cold side weight (CSW). Sides were then fabricated into thirteen NAMP sub-primals and one additional sub-primal. The sub-primals were: 112 ribeye roll, 114 shoulder clod, 116A chuck roll, 120 brisket, 189A tenderloin, 180 and 180 PSO 4 strip loin, 167 and 167A knuckle, 168 inside round, 170A gooseneck round, heel, and 193 flank steak. In addition, the 114 shoulder clod, 120 brisket, 184 top sirloin, 168 inside round, and 170A gooseneck round were weighed at .64 cm and 0 cm fat trim. After weights of the aforementioned primals and subprimals were recorded, the shoulder clod, knuckle, and gooseneck round were fabricated into value cuts. The shoulder clod was fabricated into the shoulder center (*triceps brachii* long head), shoulder top (*triceps brachii* lateral head), and top blade (*infraspinatus*). The knuckle was fabricated into the tip center (*rectus femoris*) and the tip side (*vastus lateralis*). The gooseneck round was fabricated into the bottom round trimmed flat (*biceps femoris*) and the bottom round ischiatic head (*biceps femoris* ischiatic head). After fabrication of the primals, subprimals, and value cuts, weights of each cut were recorded. Yields of primals and subprimals were calculated as a percentage of CSW and value cuts were calculated as a percentage of its subprimal and CSW.

The ADG and G:F were unaffected ($P > 0.10$)by RAC supplementation or OVX. Hot carcass weight, CCW, and REA ($P < 0.10$) tended to be improved by supplementation with RAC. Dressing percent also increased ($P < 0.05$) with supplementation. Ovariectomized heifers had lower ($P < 0.05$) DP and smaller ($P < 0.05$)

REA, and tended to have a higher ($P < 0.10$) bone maturity score and higher ($P < 0.10$) YG. Color and pH were unaffected by RAC treatment or OVX. Ractopamine tended to decrease ($P < 0.10$) heart weight and decreased ($P < 0.05$) heart weight as a percentage of LW. Ovariectomy increased ($P < 0.05$) heart and kidney weight and kidney weight as a percentage of LW. Liver weight tended to increase ($P < 0.05$) with OVX. Ractopamine increased ($P < 0.05$) 112 ribeye roll and 114 shoulder clod weight. Weight of the 189A tenderloin, 167 knuckle and 170A gooseneck round tended to increase ($P < 0.10$) with supplementation of RAC. Weight of the 112 ribeye roll decreased ($P < 0.05$) with OVX. As a percentage of CSW, the 112 ribeye roll decreased ($P < 0.05$) and the 0 cm trim 120 Brisket and .64 cm trim 180 strip loin tended to decrease ($P < 0.10$) with OVX. The shoulder top and infraspinatus were both heavier ($P < 0.05$) with supplementation of RAC. The shoulder top and infraspinatus of intact heifers had a greater ($P < 0.05$) response to RAC supplementation than OVX heifers. As a percentage of CSW, the infraspinatus tended to increase ($P < 0.10$) with RAC supplementation in INT heifers and was negatively affected in OVX heifers

Key Words: Ractopamine, Ovariectomy, Heifers, Value Cuts

1. Introduction

The beef industry is a high volume, low margin industry that is challenged with meeting the ever changing needs and expectations of consumers and regulations of governmental agencies, while maintaining profitability. Developments through research in cooperation with animal health companies have led to new products and methods which can benefit the consumer and industry. Development of feed additives that promote growth and maximize animal performance has become a topic of interest amongst producers and packers in order to maximize profit through increased weight gains with decreased economic input. Improving the efficiency of lean muscle growth is one way the industry can increase the return on it's investment by reducing costs of gain and positively impacting carcass composition and yields.

Ractopamine hydrochloride (RAC; Optaflexx®, Elanco Animal Health, Greenfield, IN) is a phenethanolamine with beta-adrenergic properties that has been shown to increase lean meat production in many animal species. The U.S. Food and Drug Administration (FDA) approved the use of RAC in cattle finishing diets in June, 2003, and its use improves carcass lean growth in feedlot cattle through increases in carcass muscling (Schroeder et al., 2004). Feedlot steers fed RAC consistently showed increased in ADG, gain:feed, carcass weight, and ribeye area (Schroeder et al., 2004). Ractopamine hydrochloride feeding appears to have its greatest impact on carcass muscling and in fact, carcass conformation scores are reportedly increased with RAC supplementation (Schroeder et al., 2004). However, the response of feedlot heifers to RAC feeding has not been as predictable. In some cases, responses similar to those in steers have been reported; however, in others, little response has been noted (Schroeder et

al., 2004; A.L. Schroeder, personal communication, 2 Aug 2005). Ovariectomization (OVX) is one way to potentially control the hormonal changes that could be responsible for variations in beef heifers' response to RAC supplementation. One caveat with OVX heifers is that they consistently have reduced gains and feed efficiency when compared to intact (INT) heifers; however, implanting with anabolic steroids appears to overcome the performance reductions noted with OVX (Kercher et al., 1958; Hortsman et al., 1982; Nygaard and Embry, 1966; Whetzal et al., 1966).

Furthermore, consumers continue to demand convenient, palatable meat products from the marketplace. Therefore, beef consumption has shifted from the consumption of roasts towards the purchase of quick and easy-to-prepare alternatives such as ground beef and steak products. In recent years, the value of the middle meats of the beef carcass has continued to increase while the value of the beef chuck and round have steadily declined. In response to this problem, the beef industry has conducted extensive research into adding value to cuts from the beef chuck and round (NCBA, 2002). These muscle profiling projects have focused on characterizing muscles of the round and chuck and identifying individual muscles within beef subprimals that could potentially be merchandised as value-added cuts. A number of new products have been developed from the shoulder clod, knuckle, and bottom round and have received marketing attention by the beef industry (NCBA, 2002). As the popularity of these new beef value cuts increases, it will be important for the beef industry to understand the impact of various industry practices on the yields and palatability of these cuts.

2. Materials and Methods

2.1. Performance Trial

Forty-eight heifers, of predominantly British breeding, were used in this study to investigate the effects of Ractopamine (RAC) supplementation and ovariectomization (OVX) on feedlot performance, carcass yield and quality traits, and subprimal and value-cut yields and meat tenderness. The heifers were randomly assigned to pens (n = 8 pens with 6 heifers per pen) and half of the pens were randomly selected for OVX, performed by a veterinarian. Within a gender subclass (OVX vs. intact; INT), half of the pens were randomly selected to receive a daily RAC supplement of 0.41mg/kg of BW; top dressed using a corn carrier, during the last 31 d of feeding. Cattle not receiving RAC were fed additional ground corn, top dressed as an equal amount to that added to the RAC-fed heifers. The resulting experimental design was a 2 × 2 factorial arrangement with two sex categories (OVX and INT) and two levels of RAC supplementation (0 and 0.41 mg/kg of BW).

Cattle were humanely managed under guidelines of the University of Georgia animal care and use committee. Cattle were treated with Ivermectin pour-on and implanted with Component TE–IH (80 mg of trenbolone acetate and 8 mg estradiol) (Vetlife, Ivy Animal Health; West Des Moines, IA) at the beginning of feeding trial. Cattle were then fed a 54:46 concentrate: corn silage TMR for 131 d (group 1; n = 4 pens) and 145 d (group 2; n = 4 pens). The concentrate diet contained 88.1 percent dry rolled corn, 10.0 percent soybean meal, 0.8 percent trace mineral salt, 0.6 percent calcium carbonate, and a 0.5 premix. At the beginning of the RAC supplementation period (last 31 days of feeding), cattle were weighed on consecutive days to determine starting

weight. Weights were also recorded after 14 days on treatment and at the end of the feeding period (31 days of supplementation). The amount of RAC top dress added to each pen was determined by the average pen weight at the start of the trial and it was adjusted on day 14, based on the 14-day average pen weight. In addition, pen feed intake was monitored in order to calculate feed efficiency. At the completion of the 31-day feeding period, the heifers were weighed on consecutive days and then transported to Athens, GA (n = 24) or Auburn, AL (n = 24) and harvested.

2.2. Harvest and Grading

Upon arrival at their harvest destination, cattle were unloaded and held overnight with free access to water. The following morning, heifers were harvested using industry standard procedures. Slaughter weight and hot carcass weight (HCW) were collected at harvest. Following an 18-24 h chill, chilled carcass weight (CCW) was recorded and carcasses were ribbed for collection of USDA yield and quality grade data, pH, and Hunter L*, a*, and b* values. Three trained, university personnel measured carcass yield and quality grade traits.

2.3. Carcass Fabrication

After carcass data were collected, the strip loin was removed from the left side of each carcass and a 2.54-cm steak was removed from the anterior end, trimmed of all visible external fat, vacuum-packaged, and frozen for subsequent intramuscular lipid analysis. Five additional steaks (2.54 cm) were then fabricated from the anterior end of the strip loin, vacuum-packaged, and randomly assigned to aging times of 2, 4, 7, 14, and 21 days. Upon completion of the aging process at 2°C, steaks were frozen and stored for subsequent tenderness determination using slice shear force.

For carcass yield calculations, the KPH fat was removed from the right sides of carcasses and they were weighed to determine the cold side weight (CSW). Sides were then be fabricated into the following thirteen NAMP subprimals and one additional subprimal: 112 ribeye roll, 114 shoulder clod, 116A chuck roll, 120 brisket, 189A tenderloin, 180 and 180 PSO 4 strip loin, 167 and 167A knuckle, 168 inside round, 170A gooseneck round, heel, and 193 flank steak. Each subprimal was weighed and recorded. In addition, the 114 shoulder clod, 120 brisket, 184 top sirloin, 168 inside round, and 170A gooseneck round were trimmed to 0.64 and 0 cm fat trim and weighed at each trim level. Recorded weights from the fourteen subprimals were compared to the CSW to determine yields on a percentage basis.

For forequarter fabrication, the forequarter and hindquarter were separated between the 12th and 13th ribs. The rib and plate were then separated from the chuck, brisket, and foreshank by cutting between the 5th and 6th ribs perpendicular to the backbone. The primal rib was removed from the plate by a straight cut from a point 2.54 cm from the outer tip of the longissimus muscle on the 12th rib end through a point 2.54 cm from the outer tip of the longissimus muscle on the 6th rib end. The chine bone was removed in order to expose the fat and lean between the feather bones and the vertebrae. The external fat and associated muscle group overlying or dorsal to the blade bone and those ventral to the blade bone (rhomboideus and subscapularis), blade bone and backstrap were removed. The rib was deboned by removing the ribs, feather bones and related cartilage while taking care not to remove the multifidous dorsi and spinalis dorsi. The lip will be removed at the natural seam to produce a 112 ribeye roll.

The primal chuck was fabricated into the 114 shoulder clod, 116A chuck roll, and 120 brisket. The shoulder clod is the group of outside muscles posterior to the elbow joint and ventral to the medial ridge of the blade bone. The 114 shoulder clod was removed from the primal chuck by natural seams extending posterior to the elbow joint and following the humerus up to the scapula. Muscles ventral to the medial ridge of the scapula are included on the clod and separated from the chuck following the natural seam back to the posterior end of the chuck. The 113 square cut chuck was removed from the brisket and foreshank by making a parallel cut to the backbone through the 1st cartilaginous juncture. The square cut chuck was further fabricated into a 116A chuck roll. To remove the neck portion, a parallel cut to the rib end between the 5th and 6th cervical vertebrae was made. The chuck tender, surface muscles and all bones were removed from the square cut chuck. Furthermore, a parallel cut to the backbone 7.6 cm ventral to the ribeye muscle was made. To remove the 120 brisket, the foreshank was removed at the natural seam and the sternum bone and deckle fat were removed.

For hindquarter fabrication, the primal flank was removed from the primal loin and round beginning at a point on the 13th rib not more than 15.2 cm from the outer tip of the longissimus muscle to a point on the sirloin end not more than 2.54 cm from the outer tip of the sirloin muscle. The 193 flank steak was then removed from the primal flank. To separate the loin and round, a cut was made between the 4th and 5th sacral vertebrae and 2.54 cm anterior to the aitch bone.

The 189A tenderloin was removed from the primal loin by following the tenderloin up into the sirloin as far as possible. The 175 short cut loin was separated from the 181 sirloin by a straight cut perpendicular to the split surface of the backbone

between the 5th and 6th lumbar vertebrae. To remove the 180 strip loin, all bones and cartilage were removed from the short loin. The flank edge of the strip loin was removed by a straight cut from a point 7.6 cm from the outside edge of the longissimus muscle on the rib end to a point which was 5.1 cm from the outer tip of the longissimus muscle on the sirloin end. To produce a 184 top sirloin, all bones and cartilage were removed from the 181 sirloin and the bottom sirloin was removed by a straight cut along the natural seam. The short loin end was parallel to the round end exposing the gluteus medius. On the round end, the biceps femoris was equal to or larger than the gluteus medius.

For primal round fabrication, the aitch bone was removed. The167 sirloin tip lying on the anterior side of the femur was removed by cutting in at the patella and following the femur. The patella was removed. Following the natural seam, the cap was removed from the sirloin tip to produce the 167A sirloin tip. Following the natural seams, the 168 inside round was removed from the 170 bottom round and femur beginning at the distal end of the femur closest to the shank. The 170A bottom (gooseneck) round was removed beginning at the heel of the round, following the natural seams and the femur, and leaving the shank attached. The heel was removed from the gooseneck round.

2.4. Value Cut Fabrication

After weights of the aforementioned primals and subprimals were recorded, the shoulder clod, knuckle, and gooseneck round were fabricated into value cuts. The shoulder clod was fabricated into the shoulder center (*triceps brachii* long head), shoulder top (*triceps brachii* lateral head), top blade (*infraspinatus*), and shoulder tender (*teres major*). The knuckle was fabricated into the tip center (*rectus femoris*) and the tip side (*vastus lateralis*). The gooseneck round was fabricated into the bottom round

trimmed flat (*biceps femoris*) and the bottom round ischiatic head (*biceps femoris* ischiatic head). After fabrication of the beef value cuts, weights of each cut were recorded. Yields of value cuts were expressed as a percentage of the subprimal from which it originated and from the CSW for analysis. Finally, three 2.54-cm steaks were cut from each value cut. Steaks were vacuum-packaged and one was frozen for subsequent lipid analysis. Excluding the top blade, the remaining steaks were randomly assigned to be aged for either 7 or 14 days and then frozen. Tenderness was subsequently evaluated by slice shear force. The top blade was fabricated in the ventral and dorsal halves. The ventral half was used for slice shear determination and the dorsal half was used for lipid extraction. Ventral top blade halves of the superficial and medial sides were then vacuum-packaged and randomly assigned to aging treatments of 7 or 14 days. Following completion of the aging period, steaks were frozen and tenderness was subsequently evaluated by slice shear force.

2.5. Lipid Extraction

Strip loin, top blade (*infraspinatus*), tip center (*rectus femoris*), and bottom round trimmed flat (*biceps femoris*) steaks designated for lipid determination were thawed, minced, frozen in liquid nitrogen and homogenized. Lipid extractions were prepared in duplicated using the procedures of Folch et al. (1957) with modifications.

Disposable aluminum drying pans were dried overnight in a 90ºC oven and equilibrated for 5 minutes in a desiccator. Tissue samples (2.5 g ± 0.1 g) were placed into labeled, conical tubes, homogenized with 10 mL of methanol and 5 mL of a methanol:chloroform mixture (2:1), and allowed to extract for 1 h. Chloroform (5 mL) and 5 mL or 1 M KCl was added to each sample and vortexed. Samples were placed in a

0ºC environment for 5 minutes, and then centrifuged at 2,000 x g for 10 min at 0ºC. The top layer was aspirated off without disturbing the meat pellet, and samples were gently poured into aluminum pans. The samples were dried overnight in a fume hood and for 15 minutes at 90ºC the following day. Following drying, samples were placed in a desiccator for 5 minutes. The samples were weighed and percent lipid was calculated using the following equation: ((pan with lipid weight – pan weight) / sample weight × 100%).

2.6. Slice Shear Force Evaluation

Slice shear force was evaluated on steaks from the following muscles: longissimus dorsi, infraspinatus, triceps brachii long head, triceps brachii lateral head, rectus femoris, vastus lateralis, biceps femoris, and biceps femoris ischiatic head using the procedure outlined by Shackelford et al. (1999). Other than steaks from the longissimus, these steaks fit into the broad category of beef value cuts. To determine shear force, 2.54-cm steaks were thawed overnight and then cooked to an internal temperature of 71°C. Frozen steaks, from a given muscle that had been aged for 2, 4, 7, 14, or 21 days (7 or 14 for the value cuts), were removed from their packaging, weighed, and stored overnight at 2°C. The following morning steaks were blotted dry and weighed to determine thawed weight. Thaw loss (%) was calculated using the following equation: (frozen wt – thawed wt) / thaw wt ×100%.

In order to monitor internal temperature, copper-constantan thermocouples, attached to a recording potentiometer, were placed in the approximate geometric center of each steak. Initial temperature and starting time were recorded and the steaks were placed onto Farberware Open Hearth electric grills. Steaks were turned at approximately

35°C and removed at 71°C. Final temperature, ending time, and cooked weight were recorded. Cook time was calculated as the ending time – the start time and cook loss (%) was calculated using the following equation: (thaw wt – cook wt) / thaw wt × 100%. The methods for slice shear evaluation for each cut are as follows:

Longissimus dorsi- After cooking to an internal temperature of 71ºC, a cut across the width, about 1 to 2 cm from the lateral end of a 2.54-cm thick strip loin steak was removed. Using a sample sizing box, a cut was made parallel to and 5 cm from the first cut across the width of the strip loin. The 5 cm long section was placed and centered on the two 45º slots and lined up with the muscle fiber angle. Using a double-bladed knife, two parallel cuts were made simultaneously through the 5 cm section producing a 1-cm thick, 5-cm long slice that was parallel to the muscle fibers.

Infraspinatus- After cooking to an internal temperature of 71ºC, a cut across the length of the top blade steak about 1 to 2 cm from the anterior end was removed. Using a sample sizing box, a cut was made parallel to and 5 cm from the first cut across the length of the flat iron. The 5-cm long section was placed and centered on the two 45º slots and lined up with the muscle fiber angle. Using a double bladed knife, two parallel cuts were made simultaneously through the 5 cm section producing a 1-cm thick, 5-cm long slice that was parallel to the muscle fibers.

Triceps brachii Long Head- After cooking to an internal temperature of 71ºC, a cut across the width, about 1 to 2 cm from the anterior end of a 2.54-cm thick shoulder center steak was removed. Using a sample sizing box, a cut was made parallel to and 5 cm from the first cut across the width of the shoulder center steak, creating a 5-cm long section. Using a double bladed knife, two parallel cuts were made simultaneously through the 5

cm section producing a 1-cm thick, 5-cm long slice that was parallel to the muscle fibers. The 45 degree box was not used, as some steaks fiber angle was not 45 degrees.

Triceps brachii Lateral Head- After cooking to an internal temperature of 71ºC, a cut across the width, about 1 to 2 cm from the posterior end of a 2.54-cm thick shoulder top steak was removed. Using a sample sizing box, a cut was made parallel to and 5 cm from the first cut across the width of the shoulder top steak, creating a 5-cm long section. Using a double bladed knife, two parallel cuts were made simultaneously through the 5 cm section producing a 1-cm thick, 5-cm long slice that was parallel to the muscle fibers. The 45 degree box was not used, as some steaks fiber angle was not 45 degrees.

Rectus femoris- After cooking to an internal temperature of 71ºC, a cut across the width, about 1 to 2 cm from the superficial end of a 2.54-cm thick tip center steak was removed. Using a sample sizing box, a cut was made parallel to and 5 cm from the first cut across the width of the tip center steak, creating a 5-cm long section. Using a double bladed knife, two parallel cuts were made simultaneously through the 5 cm section producing a 1-cm thick, 5-cm long slice that was parallel to the muscle fibers. The 45 degree box was not used, as some steaks fiber angle was not 45 degrees.

Vastus lateralis- After cooking to an internal temperature of 71ºC, a cut across the length, about 1 to 2 cm from the superficial end of a 2.54-cm thick tip side steak was removed. The anterior and posterior edges were squared to fit in the box. Using a sample sizing box, a cut was made parallel to and 5 cm from the first cut across the length of the tip side steak, creating a 5-cm long section. Using a double bladed knife, two parallel cuts were made simultaneously through the 5 cm section providing a 1-cm thick, 5-cm long

slice that was parallel to the muscle fibers. The 45 degree box was not used, as some steaks fiber angle was not 45 degrees.

Biceps femoris- After cooking to an internal temperature of 71ºC, a cut across the length, about 1 to 2 cm from the lateral end of a 2.54-cm thick bottom round steak was removed. Using a sample sizing box, a cut was made parallel to and 5 cm from the first cut across the length of the bottom round steak, creating a 5-cm long section. Using a double bladed knife, two parallel cuts were made simultaneously through the 5 cm section providing a 1-cm thick, 5-cm long slice that was parallel to the muscle fibers. The 45 degree box was not used, as some steaks fiber angle was not 45 degrees.

Biceps femoris Ischiatic Head- After cooking to an internal temperature of 71ºC, a cut across the width, about 1 to 2 cm from the superficial end of a 2.54-cm thick bottom round ischiatic steak was removed. Using a sample sizing box, a cut was made parallel to and 5 cm from the first cut across the width of the bottom round ischiatic steak, creating a 5-cm long section. Using a double bladed knife, two parallel cuts were made simultaneously through the 5 cm section providing a 1-cm thick, 5-cm long slice that was parallel to the muscle fibers. The 45 degree box was not used, as some steaks fiber angle was not 45 degrees.

Within 20 minutes of cooking, slice shear force was measured using a model 3365 Instron Universal Testing machine (Instron Corp., Norwood, MA). The blade used for shearing was 1.02 mm thick and the crosshead speed was 500 mm/min. A single slice was sheared, perpendicular to the fiber orientation, and the peak force was recorded.

2.7. Statistical Analysis

The experimental design for this study was a 2 × 2 factorial arrangement with two levels of RAC inclusion in the feed (0 and 0.41 mg/kg BW) and two gender categories (intact and ovariectomized heifers). The data were analyzed using the GLM procedures of SAS with pen serving as the experimental unit for the performance data (ADG, feed intake and gain:feed). Animal served as the experimental unit for the organ weight and carcass and fabrication data. Harvest location effects (Athens, GA and Auburn, AL) were accounted for in the model. The thaw loss, cook loss and tenderness data were analyzed as a 2 × 2 factorial arrangement with repeated measures over time. Means were generated with the LSMEANS procedure of SAS and separated using the PDIFF procedure.

3. Results

There were no interactions between RAC feeding and gender (intact vs. OVX) for feedlot performance or carcass yield or quality data. Feeding RAC (0.41 mg/kg BW) for the final 31 days of the finishing period did not affect ADG, feed intake, and gain:feed in intact or OVX heifers (Table 1). In the cooler (Table 2), RAC-fed heifers had higher ($P < 0.01$) dressing percentages and tended to produce heavier ($P = 0.07$) cold carcasses with larger ($P = 0.07$) ribeye areas. However, since 12th rib backfat was similar across treatments, USDA Yield Grade was not different between RAC-fed and control heifers. The average USDA Quality Grade for the heifers harvested in this study was low Choice, and RAC feeding did not affect either carcass maturity or marbling. Ovariectomized heifers had lower ($P < 0.01$) dressing percentages and smaller ($P = 0.05$) ribeye areas (REA) than intact heifers. Additionally, the intact heifers tended to have less ($P = 0.18$) backfat and lower ($P = 0.09$) USDA Yield Grades than OVX heifers, while carcasses

from OVX heifers tended to have lower ($P = 0.09$) carcass bone maturity scores. Instrumental (Hunter Lab) color measurements and pH taken in the longissimus dorsi were not affected by either RAC feeding or sex class (Table 2).

RAC-fed heifers tended to have lighter ($P = 0.06$) heart weights and when heart weight was expressed as a percentage of slaughter weight this difference was highly significant (Table 3). In contrast, OVX heifers had larger ($P \leq 0.03$) heart and kidneys weights and tended to have larger ($P = 0.08$) liver weights than intact heifers. When organ weights were expressed as a percentage of slaughter weight, only the kidneys were larger ($P < 0.01$) in the OVX versus intact heifers.

Carcass fabrication data (Table 4) revealed that RAC feeding increased the weight of every primal or subprimal measured. The ribeye roll, shoulder clod, and gooseneck round were significantly heavier and the tenderloin and knuckle tended ($P < 0.10$) to be heavier in the RAC-fed heifers than controls. However, when primal and subprimal yields were expressed as a percentage of cold side weight (CSW; KPH removed) there were no effects of RAC feeding in the study (Table 5). In contrast, the ribeye roll was significantly heavier and the strip loin tended to be heavier ($P = 0.06$), as a percentage of CSW, in the intact heifers compared to the OVX heifers.

Value cut yields are shown in Table 6. Sex class did not affect value cut yields on an actual weight, percent of subprimal, or percent of cold side weight basis. Likewise, RAC feeding did not impact value cut yields from the knuckle, or gooseneck round. However, the weight of flat iron (*infraspinatus*) and shoulder top (*triceps brachii*, lateral head) cuts were heavier ($P < 0.01$) in RAC-fed heifers than controls. This was due primarily to increased yields in the intact heifers (Table 7; interaction of RAC feeding

and OVX), while shoulder top and flat iron weights were not different across sex classes. Neither RAC feeding nor sex class impacted ($P > 0.25$) the intramuscular lipid content of strip loin, flat iron, tip center, or bottom round steaks (Table 8).

For tenderness evaluation, strip loin steaks were aged 2, 4, 7, 14, and 21 days, while flat iron, shoulder center, shoulder top, tip center, tip side, bottom round, and bottom round ischiatic head steaks were aged 7 and 14 days. Thaw loss (Table 9) was not different across either RAC treatment or sex class. However, thaw loss was decreased as aging time increased in the strip loin ($P < 0.01$), shoulder center ($P = 0.02$), tip side ($P = 0.06$), and bottom round ischiatic head ($P < 0.01$). The flat iron was the only cut where longer aging time resulted in greater thaw loss. Cook loss was not affected by either RAC feeding, sex class or aging time in this study (Table 10). Longissimus slice shear force was not different across RAC feeding or sex class. Tenderness in the value cuts was also not affected by either RAC feeding or sex class, except in the flat iron steaks where non RAC-fed heifers produced more tender ($P = 0.01$) product that those receiving 0.41 mg/kg BW RAC. As expected, slice shear force in the longissimus decreased ($P < 0.01$) as aging time increased. This was consistent with the findings for the shoulder center and bottom round ischiatic head; however, flat iron, tip center, tip side and bottom round steaks did not respond significantly to aging.

4. Discussion

4.1. Live Performance

Feeding RAC for the final 31 days of the finishing period did not affect feedlot performance in intact or OVX heifers. Most research suggests that RAC feeding increases ADG and gain:feed. Schroeder et al. (2004) reported increased ADG and feed

efficiency in steers and heifers fed 100, 200 and 300 mg/hd/d. Schroeder et al. (2004) found that ADG was improved by 17.1 percent, 19.6 percent, and 25.7 percent for steers, respectively. Heifer ADG was improved by 8.0 percent, 17.5 percent, and 20.4 percent, respectively. Also, Walker et al. (2006) found RAC improved ADG, efficiency of gain, carcass-adjusted ADG, and carcass-adjusted efficiency of gain. Hale (2005) reported ADG and feed efficiency to be improved in steers and heifers fed 200 mg/hd/d of RAC and Loe et al. (2005) reported feed intake was greater for RAC-fed steers. Additionally, in pigs, researchers have reported significant increases in ADG (Watkins et al., 1990; Stites et al., 1991) and reductions in feed intake (Aalhus et al., 1990; Watkins et al., 1990). In this study the finishing ration had a concentrate:corn silage of 54:46; whereas, Schroeder et al. (2004) fed a typical corn/soy-finishing ration. This may have impacted feedlot performance in this study.

Additionally, OVX had no effect on feedlot performance compared to controls. Heifers were implanted with a combination implant of 80 mg of trenbolone acetate and 8 mg of estradiol, which could have been responsible for performance similarities in OVX and INT heifers. Adams et al. (1990) mentioned that research has reversed suppression of weight gain and efficiency by concurrent administration of anabolic steroids in heifers. In agreement with these finding, Crouse et al. (1987) reported no differences in ADG between control and OVX heifers implanted with trenbolone acetate. Klindt and Crouse (1990) and Jeong et al. (1999), both found no differences in ADG of OVX and INT heifers that were not implanted during the treatment period. Contrary to these findings, Dinnusson et al. (1950), Kercher et al. (1960), Nygaard and Embry (1966), and Hortsman

et al. (1982) indicated that ovariectomy had an adverse influence on rate and efficiency of growth.

4.2. Carcass Characteristics

Increased dressing percentage reported in the RAC-treated heifers in this study is not in agreement with findings reported by Schroeder et al. (2004). However, Schroeder et al. (2004) reported a significant increase in dressing percentage in steers fed 200 and 300 mg/hd/d of RAC. Tendencies for increased carcass weight and REA is in agreement with data found by Schroeder et al. (2004), who reported that heifers treated with 200 and 300 mg/hd/d RAC had significantly heavier carcass weights and the 300 mg/hd/d group had significantly larger REA than non RAC-fed heifers. Walker et al. (2006) reported increased carcass weights with RAC feeding. Additionally, this study found that 12^{th} rib back fat and USDA yield grade was not different between RAC-fed and control heifers, which is in agreement with the findings of Schroeder et al. (2004) and Walker et al. (2006). In pigs fed RAC, there have been reports of 10^{th} rib backfat to be unaffected by treatment (Stites et al., 1991; Sainz et al., 1993b; Armstrong et al., 2004); however, other studies have reported a reduction in 10^{th} rib fat thickness (Mimbs et al., 2004; Shook et al., 2006). Carcass maturity and marbling, and thus USDA quality grade were not affected by RAC feeding in this study. Schroeder et al. (2004) and Walker et al. (2006) found no differences in marbling across all treatments levels of RAC; however, Schroeder et al. (2004) reported carcass bone maturity score was significantly lower in cattle supplemented with 300 mg/hd/d RAC.

In this study, carcass weight was not different across gender, but OVX heifers had significantly lower dressing percentages and smaller REA than INT heifers.

Ovariectomy is reported to have no effect on the hot carcass weight of heifers (Hamernick et al., 1985; Adams et al., 1990; Klindt and Crouse, 1990; Vestergaard et al., 1995; Field et al., 1996; Choat et al., 2006). Adams et al. (1990) reported dressing percent to be significantly lower with ovariectomization. Contrary to these findings, Vestergaard et al. (1995) and Field et al. (1996) reported a significantly higher dressing percentage in OVX heifers compared to intact and Hamernik et al. (1985) and Klindt and Crouse (1990) reported no significant differences. Field et al. (1996) suggests differences in dressing percent are related to the lack of reproductive tract development in OVX heifers. Crouse et al. (1985) and Field et al. (1996) report REA to be significantly smaller in OVX heifers compared to INT heifers. However, other reports have not found there to be a significant difference between OVX and INT heifers (Hamernik et al., 1985; Adams et al., 1990; Klindt and Crouse, 1990; and Vestergaard et al., 1995).

In this study, tendencies for OVX heifers to have less 12^{th} rib backfat and lower USDA yield grades compared to INT heifers were observed. Vestergaard et al. (1995) reported backfat to be significantly increased with OVX compared to INT heifers. In contrast, fat over the rib or fat at the 12^{th} rib interface is reported to be unchanged with OVX treatment compared to INT heifers (Hamernik et al., 1985; Crouse et al., 1987; Adams et al., 1990; Klindt and Crouse, 1990; and Field et al., 1996). Hamernik et al. (1985) and Adams et al. (1990) also reported that USDA yield grade was not affected by ovariectomy. In agreement with the findings of Klindt and Crouse (1990) and Field et al. (1996), carcasses from OVX heifers tended to have lower carcass bone maturity scores than INT heifers. Klindt and Crouse (1990) speculated that estrogens produced by the ovaries may hasten skeletal maturation.

4.3. Organ Weights

Results from this study showed RAC-fed heifers to have lighter heart weights. Additionally, when heart weight was expressed as a percentage of slaughter weight, the effect of RAC feeding was highly significant. Mills et al. (2002) stated that rat cardiac muscle contains mostly β1AR. Also, McNeel and Mersmann (1999) found the concentration of pig heart receptors to be 72% β1 and 28% β2. However, Mills et al. (2002) stated that a ligand's ability to express high or low affinity for a receptor is dependent on its amino acid sequence, which differs across species. The reason for the differences in the weight of the heart is not clear; however, other unpublished RAC work supports this finding (A.L. Schroeder, personal communication, 10 June 2006). Differences in heart weight as a percentage of carcass weight was exacerbated by the increased weight of the carcass noted in RAC-treated heifers.

4.4. Subprimal Yields

Carcass fabrication data revealed that RAC feeding increased the weight of every primal or subprimal measured. The ribeye roll, shoulder clod, and gooseneck round were significantly heavier and the tenderloin and knuckle tended to heavier in RAC-fed heifers than controls. This was expected since RAC feeding tended to increase carcass weights. Additionally, Schroeder et al. (2004) found heifers treated with 200 and 300 mg/hd/d RAC had significantly higher carcass weight and increased confirmation scores, which would be presumed to directly impact carcass primal yields. Studies investigating the effects of RAC on beef carcass primals is very limited; however, in pigs, weights of the trimmed primal cuts of ham, loin, belly, boston butt and picnic are increased with supplementation of RAC (Aalhus et al., 1999; Yen et al., 1990; Uttaro et al., 1993;

Crome et al., 1996). The ribeye roll was significantly heavier and the strip loin tended to be heavier in INT heifers compared with OVX. This would be expected as OVX heifers had significantly smaller REA compared with controls, which is in agreement with Crouse et al. (1987) and Field et al. (1996).

4.5. Value-Cut Yields

Yields of the value cuts from RAC-fed heifers increased on a weight basis compared to CTL, although not all the differences were significant. However, when yields were expressed on a percentage of subprimal or carcass weight basis, differences across treatment did not approach significance. This was a function of increased carcass weight noted with RAC feeding. Currently, there is no other research available on the effects of RAC feeding or ovariectomy on the Beef Value Cuts yields, described on a weight basis or percentage basis from the carcass or primal. However, research has been conducted to determine approximate yields of these cuts from beef carcasses. Muscle profiling projects have reported much of the data available on these new cuts (NCBA, 2000). Yields for the value cuts derived from this study are similar to those reported in a large population of beef carcasses, chosen to represent the beef carcass consist (NCBA, 2000).

4.6. Tenderness Evaluation

Currently, there are two primary methods for measuring shear force (i.e., tenderness) in beef longissimus steaks, the Warner Bratzler shear force (WBSF) and the slice shear force (SSF). However, there are no reported methods for determining SSF of beef value cuts. Scientists at the USDA-ARS research center in Clay Center, NE developed the SSF methodology (Shackelford et al., 2006) and suggested that SSF values

could be converted to WBS values using the following equation: longissimus WBS = (0.106283 * longissimus slice shear force) + 2.27 (S.D. Shackelford, personal communication). This equation allows SSF values to be related to literature values for WBS tests, as well as allowing SSF values to be related to current consumer thresholds for tenderness (Miller et al., 2001). Warner-Bratzler shear force values reported on the beef value cuts cooked using dry-heat are as follows: top blade (*infraspinatus),* 3.44 kg; *triceps brachii,* 4.21 kg; tip center (*rectus femoris), 3.65* kg; tip side (*vastus lateralis*), 5.28 kg; and *biceps femoris,* 4.50 kg (NCBA, 2000).

Slice shear force data for the value cuts and strip loin suggested that only the flat iron (infraspinatus) was impacted by RAC feeding, with the RAC-fed heifers having higher SSF values than CTLs. Comparing the tenderness values determined in this study to tenderness thresholds (Miller et al., 2001) by converting SSF values to WBSF values, suggests that strip loin steaks in this study would be considered tender across all treatments. In contrast, Schroeder et al. (2004) reported WBSF values of RAC-fed heifers to be in the acceptable or intermediate range using the thresholds reported by Miller et al. (2001). Schroeder et al. (2004) also reported that tenderness values for cattle fed 300 mg/hd/d RAC were tougher than those found in other RAC treatments (100 and 200 mg/hd/d) and controls. Ovariectomization had no effect on tenderness of the strip loin steaks or any other value cut. This is consistent with the findings of Crouse et al. (1987) and Adams et al. (1990), who reported tenderness, measured by WBSF, is unchanged with ovariectomization.

5. Implications

Muscle growth, fat deposition and product quality are of great concern to the red meats industry. Past research has shown the positive effects of RAC supplementation on carcass composition and consequently increased product yields. This study has shown RAC treatment to be beneficial in increasing carcass weight and subprimal weight without having any deleterious effects on carcass quality characteristics. Variability in the response of heifers to RAC supplementation, in contrast to steers, does not appear to be related to the presence of a functional ovary, as no interactions between ovariectomy and RAC supplementation were found. Diet composition, length and amount of supplementation, age of cattle at harvest, and age of cattle at time of ovariectomization, could all be influencing the results of this study and other studies. Additionally, SSF measurement of meat tenderness needs further research, especially in regards to tenderness in the beef value cuts.

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Table 1. Effects of Ractopamine feeding and ovariectomization on feedlot performance

	RAC inclusion, mg/kg BW			Gender			
Trait	0	0.41	Pr > F	Intact	Ovx	Pr > F	SEM
0-14 d ADG, kg	1.78	2.13	0.46	1.95	1.97	0.96	0.29
14-31 ADG, kg	0.84	0.77	0.75	0.75	0.86	0.64	0.15
Overall ADG, kg	1.27	1.39	0.38	1.29	1.36	0.59	0.08
DMFI, kg	11.5	12.4	0.21	12.5	11.4	0.17	0.44
As-fed FI, kg	17.5	19.0	0.21	19.1	17.4	0.17	0.70
G:F, kg/kg	0.05	0.05	0.94	0.05	0.05	0.19	0.003
F:G,kg/kg	4.13	4.09	0.92	4.39	3.83	0.20	0.26

Table 2. Effects of Ractopamine feeding and ovariectomization on carcass yield and quality traits

	RAC Inclusion, mg/kg BW			Gender			
Trait	0	0.41	Pr > F	Intact	Ovx	Pr > F	SEM
LW, kg	582.0	584.3	0.63	583.0	583.3	0.96	3.17
HCW, kg	359.7	367.8	0.09	366.3	361.1	0.22	2.47
CCW, kg	353.8	362.0	0.07	360.4	355.5	0.21	2.29
DP, %	61.8	63.0	< 0.01	62.9	61.9	< 0.01	0.14
Cooler Shrink, %	1.63	1.59	0.75	1.63	1.59	0.81	0.09
12^{th} Rib backfat, cm	1.50	1.57	0.67	1.42	1.68	0.18	0.10
Ribeye area, cm^2	79.4	84.1	0.07	84.5	79.0	0.05	1.42
KPH	2.08	2.06	0.93	2.04	2.10	0.79	0.16
Yield Grade	3.48	3.46	0.94	3.19	3.74	0.09	0.17
Lean Maturity	181.9	183.1	0.89	184.2	180.8	0.72	6.08
Bone Maturity	181.9	185.8	0.45	189.2	178.5	0.09	3.31
Overall Maturity	181.9	184.5	0.69	186.7	179.7	0.31	4.31
Marbling Score	425.6	433.8	0.85	417.1	442.3	0.57	28.6
pH	5.50	5.48	0.50	5.47	5.51	0.28	0.02
L*	34.5	36.1	0.44	34.9	35.6	0.72	1.32
a*	29.2	28.6	0.71	28.6	29.1	0.72	0.92
b*	27.3	27.3	0.99	27.0	27.6	0.69	0.99

Table 3. Effects of Ractopamine feeding and ovariectomization on organ weight and organ weight as a percentage of live weight

	RAC Inclusion, mg/kg BW			Gender			
Trait	0	0.41	Pr > F	Intact	Ovx	Pr > F	SEM
Heart, kg	1.84	1.71	0.06	1.69	1.86	0.03	0.03
Lungs, kg	3.73	3.73	0.99	3.45	4.01	0.63	0.78
Spleen, kg	0.83	0.81	0.70	0.80	0.84	0.53	0.03
Liver, kg	6.47	6.36	0.64	6.16	6.66	0.08	0.15
Kidneys, kg	1.07	1.07	0.98	0.97	1.17	< 0.01	0.02
Heart, %	0.15	0.13	0.01	0.13	0.14	0.14	0.002
Lungs, %	0.29	0.29	0.94	0.27	0.31	0.67	0.06
Spleen, %	0.07	0.06	0.32	0.06	0.06	0.97	0.002
Liver, %	0.51	0.48	0.18	0.49	0.51	0.35	0.01
Kidneys, %	0.08	0.08	0.27	0.08	0.09	< 0.01	0.001

Table 4. Effects of Ractopamine feeding and ovariectomization on carcass primal, subprimal and cut weights

	RAC Inclusion, mg/kg BW			Gender			
Subprimal	0	0.41	Pr > F	Intact	Ovx	Pr > F	SEM
Ribeye Roll	4.03	4.31	0.02	4.28	4.06	0.04	0.52
Shoulder Clod							
0.64 cm trim	8.34	9.05	0.03	8.72	8.67	0.84	0.15
0 cm trim	7.49	8.24	< 0.01	7.83	7.90	0.65	0.11
Chuck Roll	8.60	9.07	0.16	8.93	8.74	0.52	0.19
Brisket							
0.64 cm trim	4.54	4.80	0.11	4.75	4.60	0.30	0.09
0 cm trim	3.89	4.12	0.12	4.09	3.92	0.21	0.08
Tenderloin	2.27	2.48	0.07	2.37	2.39	0.82	0.06
Strip Loin							
0.64 cm trim	4.72	4.91	0.18	4.89	4.74	0.27	0.08
0 cm trim, PSO 4	3.87	4.20	0.11	4.08	3.99	0.61	0.11
Top Sirloin							
0.64 cm trim	4.61	4.78	0.47	4.71	4.68	0.90	0.15
0 cm trim	4.24	4.35	0.54	4.29	4.30	0.98	0.12
Knuckle	4.68	5.15	0.09	4.82	5.01	0.43	0.15
Peeled Knuckle	4.25	4.73	0.08	4.47	4.51	0.83	0.15
Inside Round							
0.64 cm trim	8.46	9.05	0.11	8.88	8.63	0.43	0.20
0 cm trim	7.92	8.42	0.16	8.23	8.11	0.70	0.21
Gooseneck Round							
0.64 cm trim	8.94	9.75	0.05	9.32	9.37	0.87	0.21
0 cm trim	8.08	8.91	0.04	8.52	8.48	0.89	0.19
Heel	2.00	2.13	0.11	2.05	2.07	0.77	0.04
Flank Steak	0.81	0.84	0.24	0.82	0.83	0.68	0.18

Table 5. Effects of Ractopamine feeding and ovariectomization on carcass primal, subprimal and cut weights as percentage of cold side weight

	RAC Inclusion, mg/kg BW			Gender			
Subprimal	0	0.41	Pr > F	Intact	Ovx	Pr > F	SEM
Ribeye Roll	2.43	2.42	0.87	2.51	2.33	0.04	0.04
Shoulder Clod							
0.64 cm trim	4.98	5.10	0.39	5.10	4.98	0.37	0.09
0 cm trim	4.47	4.63	0.21	4.58	4.53	0.69	0.08
Chuck Roll	5.15	5.10	0.71	5.23	5.02	0.20	0.10
Brisket							
0.64 cm trim	2.71	2.69	0.78	2.78	2.63	0.10	0.05
0 cm trim	2.32	2.31	0.81	2.39	2.24	0.06	0.04
Tenderloin	1.36	1.40	0.53	1.39	1.37	0.79	0.04
Strip Loin							
0.64 cm trim	2.83	2.77	0.32	2.87	2.73	0.06	0.04
0 cm trim, PSO 4	2.32	2.36	0.64	2.39	2.30	0.34	0.06
Top Sirloin							
0.64 cm trim	2.76	2.69	0.63	2.76	2.70	0.66	0.09
0 cm trim	2.54	2.46	0.49	2.52	2.48	0.75	0.08
Knuckle	2.79	2.89	0.49	2.81	2.87	0.69	0.09
Peeled Knuckle	2.54	2.65	0.41	2.60	2.58	0.88	0.09
Inside Round							
0.64 cm trim	5.06	5.08	0.96	5.19	4.95	0.25	0.13
0 cm trim	4.74	4.73	0.96	4.82	4.65	0.42	0.14
Gooseneck Round							
0.64 cm trim	5.32	5.48	0.40	5.45	5.34	0.57	0.12
0 cm trim	4.84	5.00	0.39	4.98	4.86	0.54	0.13
Heel	1.20	1.20	0.94	1.20	1.19	0.75	0.03
Flank Steak	0.48	0.47	0.63	0.48	0.48	0.90	0.01

Table 6. Effects of Ractopamine feeding and ovariectomization on value cut yield, expressed as actual weight, percentage of subprimal weight, and percentage of cold side weight

	RAC Inclusion, mg/kg BW			Gender			
Value Cut	0	0.41	Pr > F	Intact	Ovx	Pr > F	SEM
Shoulder Clod							
Shoulder Ctr, kg	1.34	1.44	0.15	1.40	1.38	0.70	0.04
% of clod	18.1	17.7	0.50	18.2	17.6	0.37	0.37
% of CSW	0.80	0.81	0.89	0.82	0.79	0.37	0.02
Shoulder Top, kg[a]	0.76	0.80	< 0.01	0.77	0.79	0.14	0.01
% of clod	10.2	9.9	0.34	10.0	10.1	0.81	0.21
% of CSW	0.45	0.45	0.73	0.45	0.45	0.99	0.01
Flat Iron, kg[a]	1.40	1.49	< 0.01	1.43	1.46	0.19	0.01
% of clod	18.7	18.5	0.40	18.5	18.7	0.35	0.18
% of CSW[a]	0.84	0.84	0.78	0.84	0.84	0.99	0.01
Knuckle							
Tip Center, kg	0.91	1.06	0.24	0.96	1.02	0.60	0.08
% of Knuckle	21.2	22.4	0.60	21.2	22.4	0.65	1.60
% of CSW	0.54	0.59	0.50	0.56	0.58	0.73	0.05
Tip Side, kg	1.35	1.82	0.24	1.41	1.76	0.25	0.37
% of Knuckle	31.7	39.8	0.39	32.0	39.6	0.41	5.89
% of CSW	0.80	1.04	0.33	0.82	1.02	0.41	0.15
Gooseneck Round							
Bottom Rnd, kg	3.79	4.12	0.13	3.96	3.95	0.92	0.13
% of Gooseneck	47.5	46.9	0.59	47.2	47.2	0.96	0.72
% of CSW	2.26	2.32	0.63	2.32	2.26	0.62	0.08
Btm Rnd IH, kg	0.75	0.84	0.26	0.81	0.77	0.61	0.05
% of Gooseneck	9.28	9.50	0.76	9.65	9.13	0.49	0.49
% of CSW	0.44	0.47	0.56	0.48	0.44	0.47	0.03

Table 7. Interactive effects of Ractopamine feeding and ovariectomization on Shoulder Top and Flat Iron yields expressed, as actual weight, percentage of subprimal weight, and percentage of cold side weight

	Gender					
	Intact		OVX			
RAC Inclusion, mg/kgBW	0	0.41	0	0.41	Pr > F	SEM
Value Cut						
Shoulder Top, kg	0.73[a]	0.81[b]	0.78[b]	0.79[b]	0.02	0.01
% of shoulder clod	10.1	9.9	10.3	9.9	0.83	0.29
% of CSW	0.44	0.46	0.46	0.44	0.08	0.01
Flat Iron, kg	1.34[a]	1.53[c]	1.46[b]	1.45[b]	< 0.01	0.01
% of shoulder clod	18.4	18.5	19.0	18.4	0.18	0.25
% of CSW[a]	0.81[a]	0.87[b]	0.86[b]	0.81[a]	< 0.01	0.01

[a,b,c] Means differ (P<.05).

Table 8. Effects of Ractopamine feeding and ovariectomization on the percent intramuscular lipid of Strip Loin, Flat Iron, Tip Center, and Bottom Round steaks

	RAC Inclusion, mg/kg BW			Gender			
Steak type	0	0.41	Pr > F	Intact	Ovx	Pr > F	SEM
Strip Loin	5.04	4.57	0.39	4.48	5.12	0.26	0.34
Flat Iron	9.18	9.26	0.94	9.29	9.13	0.89	0.75
Tip Center	3.88	3.85	0.88	3.78	3.95	0.34	0.11
Bottom Round	5.94	5.76	0.72	5.68	6.02	0.49	0.33

Table 9. Effects of Ractopamine feeding and ovariectomization on thaw loss (%) in Strip Loin, Flat Iron, Shoulder Center, Shoulder Top, Tip Center, Tip Side, Bottom Round, and Bottom Round Ischiatic Head (IH) steaks

	Strip Loin	Flat Iron	Shoulder Center	Shoulder Top	Tip Center	Tip Side	Bottom Round	Bottom Round IH
Main Effect								
RAC Inclusion, mg/kg BW								
0	1.13	0.89	3.87	2.67	1.38	3.51	4.17	3.71
0.41	1.09	1.01	3.20	2.49	0.93	3.31	4.57	4.16
P-value	0.82	0.69	0.06	0.73	0.23	0.73	0.30	0.10
SEM	0.13	0.20	0.24	0.37	0.27	0.41	0.27	0.19
Gender								
Intact	1.19	1.01	3.78	2.61	1.08	3.54	4.53	3.85
OVX	1.03	0.89	3.29	2.55	1.23	3.27	4.22	4.02
P-value	0.41	0.68	0.14	0.90	0.71	0.65	0.42	0.53
SEM	0.13	0.20	0.24	0.38	0.27	0.41	0.27	0.19
Aging Time								
2	1.73[a]							
4	1.39[b]							
7	1.10[c]	0.67	3.89	2.82	1.31	3.71	4.53	4.28
14	0.69[d]	1.23	3.18	2.33	1.00	3.10	4.22	3.59
21	0.64[d]							
P-value	< 0.01	< 0.01	0.02	0.06	0.32	0.06	0.28	< 0.01
SEM	0.10	0.14	0.20	0.18	0.21	0.22	0.20	0.17

[a,b,c,d] Means differ (P<.05)

Table 10. Effects of Ractopamine feeding and ovariectomization on cook loss (%) in Strip Loin, Flat Iron, Shoulder Center, Shoulder Top, Tip Center, Tip Side, Bottom Round, and Bottom Round Ischiatic Head (IH) steaks

	Strip Loin	Flat Iron	Shoulder Center	Shoulder Top	Tip Center	Tip Side	Bottom Round	Bottom Round IH
Main Effect								
RAC Inclusion, mg/kg BW								
0	20.3	26.6	21.1	28.6	26.9	27.6	24.0	23.8
0.41	19.8	27.7	23.1	29.2	27.6	26.9	23.6	25.7
P-value	0.45	0.32	0.07	0.62	0.68	0.49	0.65	0.23
SEM	0.41	0.75	0.73	0.84	1.16	0.66	0.58	1.09
Gender								
Intact	20.5	27.5	21.8	29.0	28.2	27.9	24.2	25.5
OVX	19.6	26.7	22.4	28.8	26.3	26.7	23.3	24.0
P-value	0.12	0.48	0.54	0.86	0.25	0.22	0.29	0.35
SEM	0.41	0.75	0.72	0.86	1.15	0.67	0.58	1.09
Aging Time								
2	21.2							
4	20.1							
7	19.2	26.4	22.1	29.5	27.6	28.1	23.9	25.6
14	19.5	27.8	22.1	28.3	26.9	26.4	23.7	24.0
21	20.3							
P-value	0.10	0.13	0.95	0.06	0.62	0.06	0.76	0.33
SEM	0.56	0.66	0.60	0.65	1.07	0.64	0.45	1.16

Table 11. Effects of Ractopamine feeding and ovariectomization on slice shear force (kg) in Strip Loin, Flat Iron, Shoulder Center, Shoulder Top, Tip Center, Tip Side, Bottom Round, and Bottom Round Ischiatic Head (IH) steaks

	Strip Loin	Flat Iron	Shoulder Center	Shoulder Top	Tip Center	Tip Side	Bottom Round	Bottom Round IH
Main Effect								
RAC Inclusion, mg/kg BW								
0	15.8	15.3	15.3	19.0	15.6	21.6	19.2	22.6
0.41	15.9	17.9	16.1	19.4	14.9	19.4	17.4	21.4
P-value	0.87	0.01	0.31	0.78	0.42	0.13	0.18	0.19
SEM	0.61	0.70	0.52	0.87	0.63	1.02	0.97	0.62
Gender								
Intact	16.5	16.5	15.6	19.3	15.1	20.0	17.9	21.7
OVX	15.2	17.0	15.7	19.1	15.4	20.9	18.7	22.2
P-value	0.13	0.83	0.90	0.86	0.74	0.56	0.58	0.60
SEM	0.61	0.70	0.52	0.89	0.62	1.02	0.97	0.62
Aging Time								
2	18.9[a]							
4	16.9[b]							
7	15.7[c]	16.2	16.4	19.7	15.9	20.9	18.5	22.9
14	14.1[d]	17.0	15.0	18.6	14.6	20.1	18.1	21.0
21	13.6[d]							
P-value	< 0.01	0.45	< 0.01	0.13	0.15	0.29	0.64	< 0.01
SEM	0.41	0.79	0.30	0.48	0.60	0.51	0.60	0.34

[a,b,c,d] Means differ (P<.05)

CHAPTER 6

CONCLUSIONS

In order to provide the consumer with a wholesome product, the red meats industry greatest concerns are muscle growth, fat deposition and product quality. Past research has shown the positive effects of RAC supplementation on carcass composition and consequently increased profit. Many forms of β-AA are available, but RAC is the only β-AA to be approved by the FDA as it has proven to be a safe and efficacious supplement for compositional improvements in both cattle and swine. While other forms of β-AA provide many of the same effects as RAC, they have not been proven safe for the animal or the consumer and can have various adverse effects on carcass quality. Findings from RAC studies vary somewhat, but overall, its effect of increasing the hypertrophy of muscle fibers and reducing fat deposition have a positive impact on beef and pork production.

In this study, forty-eight heifers, of predominantly British breeding, were used to investigate the effects of Ractopamine (RAC) supplementation and ovariectomization (OVX) on feedlot performance, carcass yield and quality traits, and subprimal and value-cut yields. Ractopamine supplementation proved not to be an effective means of improving feedlot performance of the heifers. Carcass composition was improved by RAC treatment, proving it to be a viable means of improving lean growth without impacting carcass quality characteristics, including tenderness. Product yields were improved with RAC feeding, due primarily to an overall increase in carcass weight, suggesting that RAC feeding will provide a greater return per animal due to these greater yields. Additionally, further research is needed to determine the

relationship between SSF and WBSF in the beef value cuts and threshold tenderness values for SSF methodologies. More research is also needed to determine the effects of varying concentrations of RAC on feedlot performance and carcass composition of RAC-fed cattle, as well as, the effects of the RAC-induced increases in lean growth on protein and energy requirements, granted feeding must follow label limits