THE INTERACTION OF RACTOPAMINE HYDROCHLORIDE, PROTEIN, AND GENDER ON LIVE ANIMAL PERFORMANCE, CARCASS CUTABILITY, QUALITY, BELLY FIRMNESS, AND FATTY ACID COMPOSITION IN FINISHING SWINE

by

JOSHUA N. SHOOK

(Under the Direction of T. Dean Pringle)

ABSTRACT

Two hundred forty crossbred barrows and gilts were used to evaluate the effects of ractopamine, protein level, and gender on performance, carcass composition and meat quality traits. Pens of a given gender were assigned to a 3×2 factorial arrangement with three dietary protein levels and two dietary ractopamine levels. Increased protein, as well as ractopamine improved finishing performance by increasing average daily gain and overall feed efficiency. Adding protein, or ractopamine into the diet, improved overall carcass composition and quality. Ractopamine-fed pigs and as well as gilts had higher iodine values while saturation levels in the belly remained in acceptable ranges for pork processors. No significant interactions between any of the three treatments regarding, performance, carcass composition, quality, or belly traits were found. These data suggest that ractopamine supplementation is an effective means of improving carcass composition without negatively impacting carcass quality, regardless of gender or dietary protein level.

INDEX WORDS: Key Words: Ractopamine, Dietary Protein, Performance, Carcass Yield

THE INTERACTION OF RACTOPAMINE HYDROCHLORIDE, PROTEIN, AND GENDER ON LIVE ANIMAL PERFORMANCE, CARCASS CUTABILITY, QUALITY, BELLY FIRMNESS, AND FATTY ACID COMPOSITION IN FINISHING SWINE

by

JOSHUA N. SHOOK

B.S., University of Georgia, 2004

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2006

THE INTERACTION OF RACTOPAMINE HYDROCHLORIDE, PROTEIN, AND GENDER ON LIVE ANIMAL PERFORMANCE, CARCASS CUTABILITY, QUALITY, BELLY FIRMNESS, AND FATTY ACID COMPOSITION IN FINISHING SWINE

by

JOSHUA N. SHOOK

Major Professor: Dr. T. Dean Pringle

Committee: Dr. Michael J. Azain
Dr. C. Robert Dove

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
December 2006

DEDICATION

I would like to dedicate this work to my entire family. To my mom, if it were not for the love, support, and prayers that you express daily, I know that I would not have had the successes that I have been so fortunate to have thus far. I consider it a great honor to be considered a "momma's boy." You're the best mom a kid could ever ask for and I owe a great part of my success to your love and devotion. To my dad, thank you for all your love, support, and teaching. You have taught me a great deal regarding hard work, dedication, and respect. Your devotion to your family has left an impact on me that will never be forgotten. Thank you both for supporting me through the good times and more importantly through the rough times. I love you both more that words could ever explain. To my sister, thank you for all of the good times, memories, and laughter, I cannot imagine my childhood without you in it. Your hard work and dedication will take you as far as you want in life, and I look forward to seeing how far you soar. To my grandparents, gran and pawpaw, your love and support goes beyond the duty of any grandparents. Without your support and guidance, my successes would not have come so easily nor with as much enjoyment. Your kindness and generosity have truly been appreciated. Lastly, to granddad and mawmaw, thank you both for your love, support, and direction. I thank each and every one of you for your support, guidance, and most importantly your love. I could not have accomplished any of my goals without your assistance. I love you all and dedicate this work to you all.

ACKNOWLEDGEMENTS

Unquestionably there are numerous individuals that I need to express my gratitude towards for contributing to my success while at UGA. First and foremost, I would like to express my deepest gratitude to Dr. Pringle. It has truly been an honor to work under your experience and leadership. Your guidance and wisdom have left an impression on me that I am forever indebted. Most importantly, you were not only a teacher, but a friend and role model, who took a personal interest in seeing that I became the best person I possibly could. Your care and devotion to your students will never be forgotten. I would also like to thank the Pringle family for their patience and generosity for allowing me to take time away from their "daddy" and husband. I feel blessed to have had the opportunity to become apart of your lives and appreciate everything you and family has done for me.

I would like to thank the other members of my committee, Dr. Mike Azain and Dr. Robert Dove. I greatly appreciate your patience and support; as well as all of the advice and aid that was given in helping make my program of study such a success. I would especially like to express my appreciation to Dr. Azain for directing the majority of the live portion of this project.

Naturally, this project could not have been completed without the help and support of many people and I would like to express my gratitude to all of them for their contribution. Special thanks go to Mr. Tom Glaze for all your help in the collection of the live performance data, as well as to Suzanne Mears and Tsung Cheng Tsai. I would

also like thank Mike Daniel and the University of Georgia Swine Center for their help in caring for the animals. Also, I would like to thank Ryan Crowe and his crew at the University of Georgia Meat Science and Technology Center for their efforts in the harvesting and collection of carcass data on all the animals used in this project. I would also like to thank Ms. Gina McKinney, Ms. Sheri Hulsey, Amelia Grant, and Abbey Williams for their help with the variety of lab work that was conducted throughout this study. Additionally, I would like to thank the rest of the graduate students for all their help and friendship; for you all made this truly an enjoyable and exciting experience.

To Clay Talton, if I were to have a big brother, I would want him to be just like you. Your friendship and inspiration mean more to me than words can begin to express. The times and experiences we had during our stay in Athens will never be forgotten. Your kindness and understanding have truly inspired and left their mark on my life. I look forward to where our lives lead us, knowing that greatness lies ahead for us both.

In addition, I would like to thank my 2006 Meat Animal Evaluation Team comprised of Abbey Williams, LaDaina Smith, Kristin Corbitt, Jason Jackson, Reid McDaniel, and Matt Marchant for their hard work, dedication, and friendship. Thank you for allowing me to be your coach and giving me two great years of fun, excitement, memories.

Finally, to my family and friends, without your love and support my adventures here at UGA would have never been as beneficial and as enjoyable as they have been. I am extremely fortunate to have such a close nit group of family and friends that have supported me with such encouragement. Thank you all so very much.

TABLE OF CONTENTS

Page

INTRODUCTION

Today's consumer is more concerned with personal health when purchasing meat at the retail counter than ever before. The swine industry is attempting to address this growing concern through the inclusion of repartitioning agents into their nutritional programs in order to decrease fat and increase muscle accretion. With the approval of such products as Paylean®, producers have seen an increase in profitability through increased weight gain, and feed efficiency; as well as an increase in carcass value due to an improved carcass leanness and yield. This in turn, produces a more consumer friendly product, resulting in a win-win situation for producers and consumers. While carcass fat reduction satisfies the consumer's demands, altered lipid metabolism and carcass fat reduction can alter fatty acid profiles, and belly firmness and thickness. A limited body of research suggests that ractopamine has little or no effect on fatty acid composition (Perkins et al., 1992; Mimbs et al., 2005, Carr et al., 2006).

Due to the increase in lean growth that accompanies ractopamine feeding, there has been some concern that pigs fed this supplement will need increased protein in their diets. In traditional diet formulation, this added protein would come in the form of soybean meal, however in addition to repartitioning agents; crystalline amino acids are becoming readily available for use in swine diets. These supplements have been marketed as alternatives to sometimes costly protein sources such as soybean meal. Depending on the cost of the natural amino acid sources, the use of crystalline amino acids could possibly reduce the cost of producing a very lean hog while maintaining

efficient growth and carcass leanness. There is also little published data about the response of pigs fed diets containing crystalline amino acids with added dietary ractopamine. In a study by Lopez et al. (1994) it was reported that low-protein, amino acid-fortified diets may be alternatives to traditional corn-soybean meal-based diets for finishing pigs. However, this study did not utilize any form of a repartitioning agent such as ractopamine hydrochloride or take gender into account. Thus, the objective of this study was to determine the response in live animal performance, ultrasound lean and fat accretion, carcass cutability and quality, belly firmness and fatty acid composition of both male and female finishing pigs fed varying levels of protein, with and without the repartitioning agent, ractopamine hydrochloride.

LITERATURE REVIEW

Ractopamine is an organic phenethanolamine with beta-adrenergic activity similar to the natural catecholamines, epinephrine and norepinephrine. These compounds bind with high affinity to beta-adrenergic receptors (βAR) in pig adipose and muscle tissue. Initially, beta-adrenergic agonists (βAA) were investigated due to their potential positive effects on human health (e.g. treating asthma, muscle atrophy, and obesity), as these compounds can influence the regulation of smooth muscle contractions, blood pressure, cardiac rate, lipolysis, and glycogenolysis (Mersmann, 1989). As a result of this research, more information regarding the mechanism of ractopamine has been learned, and now ractopamine is being used to increase animal performance and promote lean growth in both aquatic and food animal species.

βAA Mechanism

Most mammalian cell types have some form of βAR embedded in their plasma membrane. These receptors have > 400 amino acids in a continuous chain. These βAR are part of the seven-transmembrane segment receptor family. This nomenclature is indicative of the family of receptors having seven relatively hydrophobic transmembrane domains that anchor the receptor to the plasma membrance. In addition, the receptors have two extracellular recognition sites for the ligand and the correct G protein to bind (Mersmann, 1998; Garret and Grisham, 1999). It was through the systematic investigation of the physiological functions stimulated or inhibited by norepinephrine, epinephrine, and a few other compounds that led to the concept of α-adrenergic receptors

(αAR) and βAR in the late 1940's (Mersmann, 1989). The α and β receptor subclasses have respective G-proteins that serve as secondary signals (G_s and G_i) (Northup, 1985). G_s proteins stimulate adenylyl cyclase, while G_i proteins inhibit adenylyl cyclase. Alpha receptors are responsible for gut contraction and cerebral, skin and salivary gland arterioles, while β-receptors are responsible for heart rate, contractility, bronchiodilation, and stimulation of lipolysis (Mersmann, 1989). Norepinephrine and epinephrine stimulate αAR and βAR, but epinephrine is more potent than norepinephrine for αAR. Twenty years after the discovery of multiple subclasses of adrenergic receptors, Lands et al. (1967) classified β-receptors into β_1-AR and β_2-AR. An additional receptor known as β_3-AR was classified by Emorine et al. (1989). Norepinephrine is more potent for β_1-AR than for β_2-AR. The third receptor may play an important role in mediating catecholamine action. The β_3-AR are typically more sensitive to βAA than the other two receptors and are less prone to agonist-induced desensitization (Ding et al., 2000).

The distribution of receptors vary according to tissue type. The β_1 and β_2 are co-expressed in most body tissues but the β_1:β_2 ratio varies according to tissue type. For example, in the rat, the cardiac muscle cells contain mostly β_1 receptors and lung and skeletal muscle tissues are predominately β_2, while the β_3 receptors have a limited pattern of expression and are found mainly in adipose tissue (Mills, 2002). In a study by McNeal and Mersmann (1999), it was reported that porcine adipocytes have 70% β_1, 20% β_2, and 10% β_3- receptors, while muscle cells have 60% β_1, 39% β_2, and <1% β_3– receptors.

The three receptor subtypes also differ in regulation by phosphorylation, gene expression and G-protein selectivity. (Storsberg, 1996). In a report by Mills (2002), the varying range in response to a given ligand was explained by the identification of the

multiple subunits on the G-protein and how they have varying affinities for βAR in various tissues. Mills (2002) also concluded that the sequence homology for the subtypes was high across species. A ligand's ability to express high or low affinity for a βAR and to signal through G-proteins is highly dependent on its amino acid sequence, which differs across species (Mills, 2002). Thus, the effects of ractopamine can vary between species.

Ractopamine and epinephrine have similar binding affinities for βARs; however RAC has a much lower capacity to stimulate lipolysis than epinephrine, which is unrelated to its ability to bind to the receptor (Liu et al., 1989). Ractopamine is a combination of four isomers resulting from two asymmetric carbons (Mills, 2002). The RR isomer has the highest affinity for the pig β_1-AR and β_2-AR and Kd values are essentially equivalent for both subtypes. Other isomers have from 3 to 600-fold lower affinity. The RR isomer appears to be the isomer responsible for a growth response in rats and is likely the active isomer in pigs. Therefore, ractopamine can be considered non-selective in binding to either β_1-AR or β_2-AR in pigs (Mills, 2002).

The β-AA primary signal is created when a β-AA binds to a βAR, which in turn activates a G_s protein. Upon stimulation, the G_s protein activates adenylate cyclase, which is the precursor to cyclic adenine 3', 5' - monophosphate (cAMP), which then binds to the enzyme, protein kinase which phosphorylates and activates proteins such as hormone sensitive lipase and glycogen phosphorylase (Buttery and Dawson, 1987; Mersmann, 1989 and 1998; Murry et al., 1996). It is also known that phosphorylation of glycogen synthase and acetyl CoA carboxylase by protein kinase in inhibitory. This leads to the stimulation of lipolysis and glycogenolysis and an inhibition of glycogen and

fatty acid biosynthesis when cAMP levels are elevated (Mills et al., 1990; Mersmann, 1998; Garret and Grisham, 1999). Also, upon activation the βAR is phosphorylated and removed for the cell surface (Ding et al. 2000). As receptor exposure to the β-AA becomes greater than the rate of βAR replacement, the cell becomes less sensitive to stimulation and the effect of the β-AA becomes attenuated. (Spurlock et al., 1994).

Without the presence of a G-protein (G_i or G_s) adenylate cyclase cannot be activated and the secondary β-AA signal cannot become activated (Rodbell, 1980). Both G-proteins contain three subunits (α, β, and γ) and both are capable of binding with guanine triphosphate (GTP). The α-subunit becomes disassociated with the protein when it binds with GTP, and in response associates with adenylate cyclase. The adenylate cyclase actively synthesizes cAMP as long as the α-subunit remains bound to it. However, due to the α-subunits intrinsic GTPase activity, GTP is eventually hydrolyzed to GDP, leading to dissociation of the α-subunit from adenylyl cyclase and reassociation with the β and γ dimmer, regenerating the inactive heterotrimeric $G_{\alpha\beta\gamma}$ complex (Garrett and Grisham, 1999).

Changes in Adipose Tissue Metabolism Due to β-AA

Fat accretion in animals is due to a delicate balance of lipid synthesis and breakdown (Buttery and Dawson, 1987). In initial studies regarding βAR, it was shown that βAR ligands had the potential to decrease adipose tissue accretion, which led to a movement of anitobesity studies using various βAR ligands. During this early period of research, little was know about which mechanisms the ligands had a greater affect on, lipid biosynthesis, lipolysis, or both.

Lipid biosynthesis is the pathway by which fatty acids are synthesized. The process begins by utilizing acetyl-CoA, a by-product from glycolysis or fatty acid β-oxidation. A portion of the acetyl-CoA molecules are converted to malonyl-CoA by the enzyme acetyl CoA carboxylase. The acetyl-CoA and malonyl-CoA are then reduced to acetyl-ACP and malonyl-ACP (acetyl carrier proteins), and then they are combined together by β-ketoacyl-ACP synthase to form acetoacetyl-ACP, which is the first actual elongation reaction in fatty acid biosynthesis. From here the compound undergoes one dehydration and two reduction reactions to form butyryl-ACP. This cycle continues with the net addition of a two-carbon unit in each turn until the chain is 16 carbons long. The synthase cannot accommodate chains larger than 16 carbons, so the reaction stops, yielding a palmitic acid and a free ACP. Inhibition of acetyl-CoA carboxylase is strongly dependent on the phosphorylation state of the enzyme. This is a crucial connection to hormonal regulation, where binding to membrane receptors creates an active intracellular cascade involving adenylyl cyclase. When the cAMP produced by adenyly cyclase activates protein kinase, acetyl-CoA carboxylase becomes phosphorylated and in turn becomes inhibited. Without active acetyl-CoA carboxylase to convert acetyl-CoA to malonyl-CoA, fatty acid biosynthesis cannot occur.

Fat is stored in the body in the form of triacylglycerols. They are mobilized from adipocytes in response to hormone messengers such as adrenaline, glucagons, and adrenocorticotropic hormone. These signal molecules bind to receptors on the plasma membrane of the adipose cells and lead to activation of adenylyl cyclase, which later forms cAMP from ATP. The cAMP then activates protein kinase A, which phosphorylates and activates a triacylglycerol lipase that hydrolyzes a fatty acid from

carbon 1 or 3 of the triacylglycerol. The subsequent actions of diacylglycerol lipase and monoacylglycerol lipase yield fatty acids and glycerol. The fatty acid then undergoes a reaction catalyzed by acyl-CoA ligase to form fatty acyl-CoA. The fatty acyl-CoA enters a cycle of four enzyme catalyzed reactions, where the fatty acid chain becomes reduced by two carbons after each turn. The complete catabolism of one palmitic acid molecule results in eight molecules of acetyl-CoA, as well as seven molecules of $FADH_2$, and seven molecules of NADH. The acetyl-CoA can be further metabolized in the TCA cycle or it can be used as substrate in amino acid biosynthesis.

It is suggested in a study by Mills and Liu (1990), that lipid biosynthesis is more sensitive to ractopamine than is lipolysis. Additonally, Mills (1990), suggests that lipid biosynthesis is reduced by as much as 40% in pigs supplemented with ractopamine. However, later research suggests that this may not be the case (Dunshea, 1993; Liu et al., 1994). Moreover, in a study by Mills and Liu (1989), ractopamine seemed to increase lipolysis in pigs. And still others have reported that ractopamine has little effect on mobilization or oxidation of lipid from adipose tissue (Mills et al., 1990; Dunshea, 1993; Liu et al., 1994).

It is documented that ractopamine does increase levels of cAMP to allow protein kinase mediated phosphorylation of enzymes (Mills et al., 1990). However, cAMP is highly sensitive to intracellular adenosine, which can result in protein kinase A not becoming phosphorylated , thus not allowing the enzymes responsible for lipid metabolism to become activated or inhibited, and blocking the ractopamine response (Mills et al., 1990). Furthermore, Mills and Liu (1990) reported that insulin, responsible for glucose utilization and promotion of fatty acid and glycogen synthesis has the ability

to antagonize the action of ractopamine by decreasing the cell sensitivity in adipocytes. In an additional study, Peterla and Scanes (1990) reported that insulin decreased the lipolysis stimulated by beta adrenergic agonists and that it completely block the antibiosynthesis effects produced by feeding ractopamine. However, Pterla and Scanes (1990) did report that ractopamine stimulated lipolysis *in vitro,* as indicated by an increased release of fatty acids or glycerol, and inhibition of the basal rate of fatty acid biosynthesis in porcine adipose cells.

Changes in Muscle Protein Metabolism Due to β-AA

Protein turnover is a delicate balance between the two cellular processes of protein synthesis and degradation. Protein turnover is a very inefficient process due to the great expenditure of energy during breakdown and resynthesis of proteins. However, Reeds (1989), states this is a necessary processes for maintaining available pools of amino acids, repairing erroneous proteins, and removing proteins not properly incorporated into their subcellular locations. It was suggested by Young et al. (1975), that anywhere from 15 to 25% of the energy consumption of growing animals is used for protein turnover.

The β-adrenergic agonists have been shown to increase muscle accretion in addition to decreasing fat accretion (Yang and McElligott, 1989). In a study by Mills (2002), it was reported that the primary effect of β-AA is to cause fiber hypertrophy without an associated increase in DNA, which would indicate that protein synthesis, degradation, or both are affected. In most cases, β-AA have the greatest effect on protein degradation. This may be due to their impact on the cysteine proteinase, μ- and m- calpain, and their inhibitor, calpastatin. These compounds are believed to play a

major role in protein turnover. In a study by Pringle et al. (1993), it was reported that the calpain activity of β-AA supplemented lambs was significantly decreased in addition to a 73% increase in calpastatin activity. Furthermore, in a report by Garber et al. (1976), it was determined that epinephrine decreased the release of amino acids from muscle, and since β-AA and the hormone epinephrine have similar effects on the adenylate cyclase system, this could explain the decrease in protein degradation seen when supplementing growing animals with β-AA.

In a study measuring protein synthesis, Helferich et al. (1988) reported a 50% increase in actin synthesis following β-AA supplementation. Moreover, Anderson et al. (1989) suggest that increased protein accretion with β-AA was due to an initial decrease in protein degradation followed by and increase in protein synthesis.

Regardless of the differences in data, it is commonly accepted that the increased muscle growth associated with β-AA supplementation is due primarily to hypertrophy. A direct link between cAMP and transcriptional regulation of the genes for myosin heavy chain in cardiomyctes (Gupta et al., 1996) and bovine calpastatin (Cong et al., 1998) has been shown and since β-AA's significantly affect cAMP levels, this may provide evidence of how β-AA's directly affect protein synthesis and thus protein turnover. In addition to the direct effects of cAMP, βAR have been shown to activate alternative signaling cascades (MAP kinase) in common with insulin (Luttrell et al., 1998). Insulin promotes protein synthesis and inhibits protein degradation and the signaling cascades have been linked to protein metabolism (Dennis et al., 1991). With the involvement of these pathways in the β-AA and βAR alterations of protein metabolism, additional

research needs to be conducted to determine the specific effects of β-AAs on protein metabolism.

Ractopamine Stimulated changes in Swine Growth Performance

It is generally reported that dietary ractopamine supplementation increases average daily gain, improves feed efficiency, and decreases feed intake in swine. However, the effect of feeding ractopamine on daily gain, feed efficiency, and intake varies from study to study. Many studies have reported an improvement in feed efficiency with ractopamine supplementation (Crome et al., 1996; Dunshea et al., 1998; Mimbs et al., 2005; Carr et al., 2006a). Alternatively, few studies have actually shown that ractopamine did not affect feed efficiency (Crenshaw et al., 1987). Even though improved feed efficiency is generally accepted, whether the improvement in feed efficiency is due to increased gain, decreased feed intake or both has not been consistently shown. Research has shown that ractopamine improved average daily gain (Crome et al., 1996; Dunshea et al., 1998; and Carr et al., 2006a) and decreased feed intake (Uttaro et al., 1993; Crome et al., 1996; Mimbs et al., 2005). However, others studies have shown no improvement in average daily gain (Mimbs et al., 2005) as well as little change in feed intake due to dietary ractopamine (Carr et al., 2006a). Factors such a level of ractopamine feeding, protein supplementation, genotype, age, starting weight, gender, and environment, are all factors that may influence the response of pigs to ractopamine supplementation and are likely responsible for inconsistencies reported in various performance trials.

In past studies, it was reported that live animal response to dietary ractopamine is not constant over the course of the feeding period (Williams et al., 1994; Kelly et al.,

2003). More specifically, the ractopamine response in the animal performance increases rapidly, plateaus, and then seems to decrease during the course of the ractopamine feeding period (Williams et al., 1994; Kelly et al., 2003). The ractopamine response diminishes over time, due to either down regulation or desensitization of the β_1-adrenergic receptors (Moody et al., 2000). Most research has focused on constant dietary concentration of ractopamine, however in a study by See et al. (2004) it was reported that a ractopamine step-up program produced more consistent and desirable results than a step-down feeding regime. Past research from Watkins et al. (1990) reported that the optimal efficacious dose for average daily gain and feed efficiency was between 14 and 18 ppm for the maximum response when a 16% crude protein diet was fed.

Many researchers have conducted trials with ractopamine using a 16% crude protein diet (Yen et al., 1990; Stites et al., 1991; Sainz et al., 1993) and found positive effects on average daily gain, feed intake, and feed efficiency. However others have used diets at or below 13% crude protein and found minimal improvement in animal performance (Adela et al., 1990; Mitchell et al., 1990). Additionally, in a study by He et al. (1993) where diets of 17 or 20% crude protein were fed, the additional (3%) crude protein did not influence pig performance.

In today's commercial swine industry, the use of crossbreeding to increase heterosis for growth is becoming extremely common, if not the norm. It is well defined that different breeds of swine have varying levels of lean gain potential, which becomes a very important trait for swine producer due to increased ADG and feed efficiency being the main factors affecting profitability. However, with the increase in the mixing of breed genetics, little literature is available on the effect of ractopamine across various

swine breeds. However, in a study by Gu et al. (1991), it was reported that a favorable heterosis for growth was found in crossbred market hogs; yet no significant interaction between genotype and ractopamine existed.

It was stated in Metabolic Modifiers (1994), that younger pigs may potentially have fewer βAR and lower affinity of β-AA than older pigs. This is probably the reason that Sainz et al., (1993) found no effect of ractopamine in younger pigs when compared to the 30% greater response in ADG and feed efficiency seen when cimaterol was fed to older pigs.

Finally, studies have investigated the interaction of swine gender and β-AA supplementation on growth performance. Several studies have determined that ractopamine improved ADG and feed efficiency regardless of sex (Dunshea, 1991; Dunshea et al., 1998; See et al., 2004; Carr et al., 2005). Furthermore, in the report by Dunshea (1991), it was stated that ractopamine supplementation tended to normalize gender differences in performance.

Ractopamine Stimulated Changes in Pork Carcass Yield and Quality Measures

Many researchers have found that feeding ractopamine decreases average backfat (Watkins et al., 1990; Yen et al., 1990; Bark et al., 1992) with 10^{th} rib backfat being the primary site of reduction (Watkins et al., 1990; Yen et al., 1990; Bark et al., 1992; Crome et al., 1996; See et al., 2004; Carr et al., 2005b). However, other studies have found no reduction in 10^{th} rib backfat depth (He et al., 1993; Sainz et al., 1993b; Carr et al., 2005a; Weber et al., 2006). Fat at the 10^{th} rib is the most important backfat measurement to report due to its significance in determining fat free lean.

More consistent than reports regarding backfat, are findings regarding carcass lean. Ractopamine is consistently reported to increase carcass lean. In numerous studies, longissimus muscle area (LMA) was significantly increased with dietary ractopamine (Herr et al., 2002; Schinkel et al., 2002; See et al., 2004; Car et al., 2005a; Carr et al., 2005b; Weber et al., 2006). Carcass muscle scores were shown to be increased as well in studies by Crome et al. (1996) and Mimbs (2004). Furthermore, very few studies have not reported an increase in LMA with ractopamine supplementation (Sainz et al., 1993b).

These improvements in overall carcass leanness are a result of the ractopamine induced changes in lipid biosynthesis, lipolysis, and protein turnover that were previously discussed. Additional studies involving carcass dissection have further verified the improvement in carcass lean:fat ratios seen by feeding ractopamine hydrochloride (Mitchell, et al., 1990; Watkins et al., 1990; and Bark et al., 1992).

In the past, pork quality has been of little concern to producers and the industry. However, with ever increasing concern for quality in other red meat species, the pork industry is beginning to pay closer attention to pork quality and its effects at the retail level. Ractopamine has been shown to have little negative effect on pork quality measures. Ultimate pH and L* values were not significantly affected by dietary supplementation of ractopamine in several studies (Aalhus et al., 1990; Sainz et al., 1993b; Carr et al., 2005a; Carr et al., 2005b). However, several studies have shown a decrease in a* and b* values with RAC supplementation (Uttaro et al., 1993; Carr et al., 2005a; Carr et al., 2005b). Lower a* values indicate lower levels of oxymyoglobin and is possibly due to a dilution effect caused by muscle fiber hypertrophy or possibly due to a shift in intermediate fibers to white fibers (McKeith et al., 1988, 1990). Some studies

have seen improvement in NPPC color, firmness (Watkins et al., 1990), and marbling scores (Aalhus et al., 1990; Mimbs, 2004); however others have seen no effect (Crome et al., 1996; McKeith and Ellis, 2001; Carr et al., 2005a, 2005b). In other quality measures, Carr et al. (2005b) reported that loin chop drip loss and intramuscular fat percentages were unaffected by ractopamine, while shear force values were increased by dietary ractopamine and belly firmness was decreased. However in an additional study conducted by Carr et al. (2005a), drip loss percentages were decreased with ractopamine and belly firmness values were unaffected. Conversely, Weber et al. (2006) reported no effect of ractopamine on loin chop drip loss percentage or belly firmness, but did see a decrease in loin intramuscular fat with dietary ractopamine. Thus it appears that ractopamine will not create quality defects and lead to economic loss due to reduced meat quality.

Ractopamine has been shown to have little or no effect on fatty acid composition in different depots of pork carcasses (Lee et al., 1989; McKeith et al., 1990; Engeseth et al., 1992; Perkins et al., 1992; Carr et al., 2005b). In the studies by Lee et al. (1989) and Engeseth et al. (1992), ractopamine feeding reduced stearic acid levels in subcutaneous fat and increased linolenic acid. Furthermore ractopamine increased the linoleic acid content in subcutaneous backfat (Carr et al., 2005b) and in intramuscular fat collected from the *longissimus dorsi* (Perkins et al., 1992). Additionally, Weber et al. (2006) reported an increase in linoleic acid and total unsaturated fatty acids in the inner middle layer of subcutaneous fat and a trend for there to be an increase in polyunsaturated fatty acids in the outer layer with changes in 18:2 and 20:5 levels. Moreover, in the same

study, there was no effect on fatty acid composition of loin muscle fat and there was a tendency for ractopamine to decrease total saturated fat in fat from the belly.

Muscle Growth

The primary components of a given muscle are the constituent muscle fibers. Therefore, muscle mass is highly dependent on the number and size of those fibers. Current research suggests that animals with greater numbers of muscle fibers of moderate size produce more meat of better quality (Rehfeldt et al. 2000). Muscle fiber number is mainly determined by genetic and environmental factors which are capable of influencing prenatal myogenesis, which is responsible for muscle cell multiplication and fiber number.

Prenatal development

During the development of the embryo, myoblasts are formed from myogenic cells in the mesodermal region (Rehfeldt et al. (2000). These cells are believed to enter the myogenic lineage and are able to proliferate and divide to establish a pool of myoblasts. Once a pool has been established, special signals cause the myoblasts to exit the cycle, stop dividing, and begin to differentiate. At this time they begin to express muscle cell-specific proteins and finally fuse to form multinucleated myotubes.

During the myogenesis process, muscle fibers develop from two distinct populations. Primary fibers are established during the initial stages of myoblast fusion, and these fibers will be the framework for the larger population of smaller secondary fibers (Beermann et al., 1978; Miller et al., 1993). These smaller secondary fibers are formed from fetal myoblasts during a second wave of differentiation. The second populations of myoblasts do not form fibers but stay close to the myofibers. These cells

are commonly referred to as satellite cells, and they are capable of dividing and serving as a source of new myonuclei during postnatal growth (Moss and Leblond, 1971; Schultz, 1974). These cells contribute to the growth of muscle fibers as well as aid in regeneration processes.

Postnatal Growth

The increase in muscle mass during postnatal growth is mainly due to muscle hypertrophy. This hypertrophy is due to an increase in muscle fiber size, not number, which is accompanied by the prolific activity of the satellite cells, which provide the new nuclei that will be incorporated into the muscle fibers. It is commonly accepted that muscle fiber number remains unchanged in mammals and birds after birth (pig-Fiedler, 1983; cattle-Wegner et al., 2000; chicken-Smith, 1963; quail-Fowler et al., 1980). Muscle fibers grow in size towards a plateau, whereas fiber number remains constant after birth.

Postnatal muscle fiber hypertrophy depends on the total number of muscle fibers within a muscle. Growth rate has been shown to be dependent of the total number of muscle fibers. When lower numbers of muscle fibers are present, growth rate tends to be higher than when greater numbers of fibers are present. This is concluded from the fact that muscle fiber number is inversely correlated to muscle fiber thickness at the end of an intensive growth period (Rehfeldt et al. (2000). On the other hand, both fiber number and thickness are positively correlated with muscle cross-sectional area. This antagonistic relationship between fiber number and thickness is explained by Rehfeldt et al. (2000) as an equalization of energy distribution among all the fibers. However, since the correlation is not – 1.0, some animals do exhibit fast-growing fibers despite high fiber

numbers. In summary, lean growth depends on the number of prenatally formed fibers and on the degree of their postnatal hypertrophy. However, the potential for lean growth of an animal largely depends on the number of prenatally formed muscle fibers, because the postnatal increase in muscle size is limited by genetic and physiological factors.

Protein in the Diet

Proteins are comprised of amino acids, and these amino acids are released and absorbed during digestion. It is known that pigs fed diets deficient in protein do not grow or reproduce efficiently. However, it is not necessarily the protein that is responsible for the decreased performance but the deficiencies in essential amino acids available to the animal that causes the decrease in performance. It was found that of the 20 different amino acids that commonly occur, that some of them are essential to the pig, meaning the pig cannot synthesize these amino acids and they must be provided in the diet. Due to this problem, swine diets must be evaluated to ensure the all of the essential amino acid requirements are being met so as to obtain normal growth and reproduction. However, this can become problematic due to the variability in requirements depending on breed, sex, age, and growth potential.

Pigs are generally fed using the ideal protein concept. The ideal protein concept has been discussed by numerous authors and is generally defined as a protein source that contains a perfect balance of amino acids, both among the essential amino acids and between the essential and nonessential amino acids. Estimates as to the proportions of amino acids in ideal protein for growing pigs have been derived from an examination of various types of data including the composition of pig tissue, sow's milk, and a combination of individual estimates of amino acid requirements (Lewis, 2001). Whether

there is one ideal proportion among the amino acids has been questioned (Lewis et al., 1977) because it is evident that there is a difference in the ideal pattern for maintenance and tissue synthesis. Thus, it is believed that the ideal proportion will change over time as the animal changes it needs for maintenance and tissue growth. For these reasons, the swine industry has moved from formulating diets based on crude protein to creating diets based on specific amino acid requirements. Although crude protein level must be presented on the feed label, it is more precise and accurate to develop swine feeds based amino acid requirements. This has become easier since the amino acid profiles of feedstuffs as well as the specific amino acid requirements of swine are better understood than in previous times (Lewis, 2001).

As the National Research Council has developed various swine nutrition requirements depending on the animal's weight or phase of production, several studies have focused on whether these requirements actually allow the animal to maximize production and growth. In a study by Cromwell et al. (1993), it was shown that NRC requirements, at the time, were accurate for 50 to 100 kg barrows; however, the NRC requirements for gilts of the same weight were too low. Additionally, in a study by Cline et al. (2000), it was reported that gilt performance did not improve with lysine levels greater than .80% of the diets; however, higher levels of lysine did improve carcass leanness. With consumer demands for leaner pork prompting the swine industry to select pigs based on carcass leanness, keeping current swine nutrition requirements accurate may become more difficult.

Since amino acids have become such an important part of swine diet formulation, synthetic amino acids have become an area of interest of many researchers and

nutritionists. In the past, the amino acid requirements for pigs were met using intact proteins contained primarily in corn and soybean meal. This was the easiest and most economical way to get the required amino acids in the diet, in the correct proportions. However, some crystalline amino acid sources are becoming readily available at prices that make them affordable for use in formulating swine diets. There are currently four crystalline amino acid sources (lysine, methionine, tryptophan, and threonine), several mixtures (lysine and tryptophan), and some liquid forms (lysine and methionine) available for inclusion in swine diets.

Lysine is the most popular synthetic amino acid on the market today, with most of it being used in the swine industry. Lysine is available naturally in two forms –D and –L, in which the –D form is of little use to mammals. Lysine is not capable of reversible transamination, which is necessary for the conversion of D-lysine to L-lysine. Manufacturers use a fermentation process to increase the yield of the L-lysine isomers, which is usually in the monohydrochloride (L-lysine · HCl) form. This form contains 98.5% L-lysine · HCl and is equivalent to 78.8% actual lysine. Much like lysine, threonine is not capable of reverse transamination either. In a study by West and Carter (1938), it was found that rats could only utilize L-threonine, and it is assumed that pigs are similar however it has never been tested. Feed-grade threonine is in the L-form only and is 98.5% pure.

Methionine in the D-form is easily utilized by most species including swine. Chung and Baker (1992) reported that DL-methionine can readily replace L-methionine. Feed grade sources of methionine are available as DL-methionine and as a methionine

hydroxyl analog. Either of these forms seem sufficient for supplementation to swine (Lewis, 2001).

Pigs seem to be capable of utilizing D-tryptophan, although not a well as the L-form (Lewis, 2001). There is some debate over the biological activity of the D-form; however the feed-grade form is only available in the L-form which is 98.5% pure.

Several studies have investigated the potential of reducing crude protein levels of swine diets and supplementing these diets with crystalline amino acids. In early studies this was done to reduce cost of diets that were high in costly soybean meal; however in more recent studies, emphasis has shifted from reducing feed cost to reducing excess nitrogen excretion. A study by Obrock (1997) where diets were reduced by 4 percentage points in crude protein and fortified with crystalline amino acids, resulted in a 75% decrease in aerial ammonia and a 70% reduction in odor. When crude protein levels of a diet are reduced by approximately two percentage points and supplemented with crystalline amino acid, performance is equal to normal levels achieved with traditional corn-soybean meal diets (Lewis, 2001). However if crude protein is reduced by more than two percentage points, animal performance becomes more variable. Reduction of three points can sometimes be achieved with no negative effects; however reductions of four percentage units results in decreased lean gain (Knowles et al., 1998). Why negative effects on animal performance with low-protein diets fortified with crystalline amino acids occur is still unknown. Several ideas involving deficiencies in other essential amino acids, poor efficiency of utilization of the crystalline amino acids, improper vitamin or mineral balances, and improper balance of amino acids have all been considered in regards to the diminished performance (Lewis, 2001).

Effects of Protein Level on Carcass Characteristics

With the consumer demand for lean, high quality pork increasing, the need to produce such a product is greater than ever. In several previous studies it was concluded that feeding high protein diets to finishing swine improves overall carcass leanness (Davey and Morgan, 1969; McConnell et al., 1971; Davey, 1976). In addition to improvements in overall carcass leanness, intramuscular fat was also shown to be decreased, which may have an effect on muscle tenderness. A study by Karlsson et al. (1993), supported this idea, suggesting that the decrease in intramuscular fat present in *longissimus dorsi* chops from pigs fed higher protein diets would increase shear force values. Moreover, Cline et al. (2000), increased levels of lysine in the diet and reported a linear decrease in backfat, over the treatment levels, and a quadratic increase in loin muscle area. They suggest that these changes in carcass measures were possibly due to the fact that more energy was utilized in the deamination of excess amino acids, required for excreting the excess nitrogen, and that resulted in less net energy available for deposition of adipose tissue. Finally, in data presented by Lopez et al. (1994), carcass muscling and average backfat were improved with increasing the level of lysine in the diet, however, the source of amino acid supplementation did have an effect (intact vs. synthetic). Furthermore, measured carcass quality traits were not affected in their study.

Summary

Based on the information from previous research, it is evident that more research needs to be conducted to address the lapses in knowledge regarding the effects of dietary protein/amino acid requirements and repartioning agents on pig performance, pork carcass composition, and pork meat quality. Inconsistencies in the research could grow

worse with continued selection for lean growth in pigs as an attempt to meet the consumer demand for leaner pork. As the use of animals that are genetically prone to deposit less fat and more muscle are used in conjunction with repartioning agents and synthetic amino acids, concerns about meat quality must be addressed. State of the art feeding practices seem to be aiding in the movement to production of leaner pigs, however, the effects on pork meat quality are not well understood. Additionally, little research has been conducted to evaluate the interaction of synthetic amino acids and ractopamine. As these new products become more readily available, at an economical price, they will be utilized in conjunction with each other. Additional research must be conducted to evaluate the interaction of these new supplements and how they may impact swine growth, carcass composition, and pork quality.

Literature Cited

Aalhus, J.L., S.D.M. Jones, A.L. Schafer, A.K.W. Tong, W.M. Robertson, J.K. Merrill, and A.C. Murray. 1990. The effect of ractopamine on performance, carcass composition, and meat quality of finishing pigs. Can. J. Anim. Sci. 70:943-952.

Adeola, O., E.A. Darko, P. He, and L.G. Young. 1990. Manipulation of porcine carcass composition by ractopamine. J. Anim. Sci. 68:3633-3641.

Anderson, D.B., E.L. Veenhuisen, W.P. Waitt, R.E. Paxton, and D.H. Mowrey. 1989. The effect of ractopamine on nitrogen retention, growth performance and carcass composition of finisher pigs. J. Anim. Sci. 82. (Suppl 2):52 (Abstr.)

Bark, L.J., T.S. Stahly, G.L. Cromwell, and J. Miyat. 1992. Influence of genetic capacity for lean tissue growth on rate and efficiency of tissue accretion in pigs fed ractopamine. J. Anim. Sci. 70:3391-3400.

Beerman, D.H., R.G. Cassens, and G.J. Hausman. 1978. A second look at fiber type differentiation in porcine skeletal muscle. J. Anim. Sci. 46:125-132.

Buttery, P.J., and J.M. Dawson. 1987. The mode of action of beta-agonists as manipulators of carcass composition. Pages 30-35. In Beta-Agonists and their effects on animal growth and carcass quality. J.P. Hanrahan (Ed.) Elsevier Applied Science, New York.

Carr, S.N., D.J. Ivers, D.B Anderson, D.J. Jones, D.H. Mowrey, M.B. England, J. Killefer, P.J. Rincker, and F.K. McKeith. 2005a. The effects of ractopamine hydrochloride on lean carcass yields and pork quality characteristics. J. Anim. Sci. 83:2886-2893.

Carr, S.N., P.J. Rincker, J. Killefer, D.H. Baker, M. Ellis, and F.K. McKeith. 2005b. Effects of different cereal grains and ractopamine hydrochloride on performance, carcass characteristics, and fat quality in late-finishing pigs. J. Anim. Sci. 83:223-230.

Chung, T.K., and D.H. Baker. 1992. Utilization of methionine analogs and isomers by pigs. Can. J. Anim. Sci. 72:185-188.

Cline, T.R., G.L. Cromwell, T.D. Crenshaw, R.C. Ewan, C.R. Hamilton, A.J. Lewis, D.C. Mahan, and L.L. Southern. 2000. Further assessment of the dietary lysine requirement of finishing gilts. J. Anim. Sci. 78:987-992.

Cong, M., V.F. Thompson, D.E. Goll, and P.B. Antin. 1998. The bovine calpastatin gene promoter and a new N-terminal region of the protein are targets for c-AMP-dependent protein kinase activity. J. Biol. Chem. 273:660-666.

Crenshaw, J.D., P.M. Swanteck, M.J. Marchello, R.L. Harrold, R.C. Zimprich, and R.D. Olson. 1987. Effects of phenethanolamine (ractopamine) on swine carcass composition. J. Anim. Sci. 65(Suppl.1):308

Crome, P.K., F.K. McKeith, T.R. Carr, D.J. Jones, D.H. Mowrey, and J.E. Cannon. 1996. Effect of ractopamine on growth performance, carcass composition, and cutting yields of pigs slaughtered at 107 and 125 kilograms. J. Anim. Sci. 74:709-716.

Cromwell, G.L., T.R. Cline, J.D. Crenshaw, T.D. Crenshaw, R.C. Ewan, C.R. Hamilton, A.J. Lewis, D.C. Mahan, E.R. Miller, J.E. Pettigrew, L.F. Tribble, and T.L. Veum. 1993. The dietary protein and(or) lysine requirements of barrows and gilts. J. Anim. Sci. 71:1510-1519.

Davey, R.J. 1976. Growth and carcass characteristics of high- and low-fat swine fed diets varying in protein and lysine content. J. Anim. Sci. 43:598-605.

Davey, R.J., and D.P. Morgan. 1969. Protein effect on growth and carcass composition of swine selected for high and low fatness. J. Anim. Sci. 28:831-836.

Dennis, P.B., S. Fumagalli, and G. Thomas. 1999. Target of rapamycin (TOR): balancing the opposing forces of protein synthesis and degradation. Curr. Opin. Genet. Dev. 9:49-54.

Ding, S.-T., R.L. McNeel, E.O. Smith, and H.J. Mersmann. 2000. Modulation of porcine adipocytes β-adrenergic receptors by β-adrenergic agonist. J. Anim. Sci. 78:919- 926.

Dunshea, F.R., R.H. King, P.J. Eason, and R.G. Campbell. 1998. Interrelationships between dietary ractopamine, energy intake, and sex in pigs. Aust. J. Agric. Res. 49:656-574.

Dunshea, F.R. 1993. Effect of metabolism modifiers on lipid metabolism in the pig. J. Anim. Sci. 71:1966-1977.

Dunshea, F.R. 1991. Factors affecting efficacy of beta-agonists for pigs. Pig News and Information. 12:227-231.

Emorine, L.J., K.O. Lee, W.G. Bergen, W.G. Helferich, B.K. Knudson, and R.A. Merkel. 1992. Fatty acid profiles of lipid depots and cholesterol concentration in muscle tissue of finishing pigs fed ractopamine. J. Food Sci. 57:1060-1062.

Engeseth, N.J., K.O. Lee, W.G. Bergen, W.G. Helferich, B.K. Knudson, and R.A. Merkel. 1992. Fatty acid profiles of lipid depots and cholesterol concentration in muscle tissue of finishing pigs fed ractopamine. J. Food Sci. 57:1060-1062.

Fiedler, I. 1983. [Postnatal growth of muscle fibers in pigs.] Tagungsber. Akad. Landwirtschaftswissenschaften, Berlin, Germany. 209:87-94.

Fowler, S.P., D.R. Champion, H.L. Marks, and J.O. Reagan. 1980. An analysis of\ skeletal muscle response to selection for rapid growth in quail (*Coturnix coturnix japonica*). Grwoth 44:235-252.

Garrett, R.H., and C.M. Grisham. 1999. Pages S1-S7 in Biochemisrty. Saunders College Publishing, Orlando.

Garber, A.J., I.E. Karl, and D.M. Kipnis. 1976. Alanine and glutamine synthesis and release from skeletal muscle. Biochem. J. 251:851-857.

Gu, Y., A.P. Schinckel, J.C. Forrest, C.H. Kuei, and L.E. Wakins. 1991. Effects of ractopamine, genotype, and growth on finishing performance and carcass value in swine: II. Estimation of lean growth rate and lean feed efficiency. J. Anim. Sci. 69:2694-2702.

Gupta, M.P., M. Gupta, S. Jakovcic, and R.Zak. 1996. Catecholamiones and cardiac growth. Mol. Cell. Biochem. 163-164:203-210.

He, P., F.X. Aherne, J.R. Thompson, A.L. Schaefer, and J.K. Merrill. 1993. Effect of ractopamine on carcass characteristics and joint cartilage soundness in finishing pigs. Can. J. Anim. Sci. 73:169-176.

Helferich, W.G., D.G. Jump, D.M. Skjaerlund, W.G. Bergen, R.A. Merkel, and D.B. Anderson. 1988. Pretranslational regulation of skeletal muscle alpha actin synthesis in pigs fed ractopamine. FASEB J. 2:3096-3100.

Kelly, J.A., M.D. Tokach, and S.S. Dritz. 2003. Weekly growth and carcass response to feeding ractopamine (Paylean®). Pages 51-58 in Proc. Am. Assoc. Swine Vet., Perry, IA.

Karlsson, A.A., C. Enfalt, B. Essen-Gustavsson, K. Lundstrom, L. Rydhmer, and S. Stern. 1993. Muscle histochemical and biochemical properties in relation to meat quality during selection for increased lean tissue growth rate in pigs. J. Anim. Sci. 71:930-938.

Knowles, T.A., L.L. Southern, T.D. Bidner, B.J. Kerr, and K.G. Friesin. 1998. Effects of dietary fiber or fat in low-crude protein, crystalline amino acid-supplemented diets for finishing pigs. J. Anim. Sci. 76:2818-2832.

Lands, A.M., A. Arnold, J.P. McAuliff, F.P. Lunduena, and T.G. Brown Jr. 1967. Differentiation of receptor systems activated by sympathomimetic amines. Nature. 214:597-598.

Lee, K.O., W.G. Bergen, W.G. Helferich, N.J. Engeseth, S.M. Stoik, and R.A. Merkel. 1989. Does ractopamine affect fatty acid profiles in lipid depots of finishing pigs? J. Anim. Sci. 67 (suppl 1):151.

Lewis, A.J. Amino acids in swine nutrition. p.131-150 in Swine Nutrition. A.J. Lewis and L.L. Southern (Ed.). CRC Press LLC, Boca Raton, FL.

Lewis, A.J., E.R. Peo Jr., P.J. Cunningham, and B.D. Moser. 1977. Determination of the optimum dietary proportions of lysine and Tryptophan for growing pigs based on growth, food intake, and plasma metabolites. J. Nut. 107:1369-1376.

Liu, C.Y., A.L. Grant, K.H. Kim, S.Q. Ji, D.L. Hancock, D.B. Anderson, and S.E. Mills. 1994. Limitations of ractopamine to affect adipose tissue metabolism in swine. J. Anim. Sci. 72:62-67.

Liu, C.Y., and S.E. Mills. 1989. Determination of the affinity of ractopamine and clenbuterol for the beta-adrenoceptor of the porcine adipocytes. J. Anim. Sci. 67:2937-2942.

Lopez, J., R.D. Goodband, G.L. Allee, G.W. Jesse, J.L. Nelssen, M.D. Tokach, D. Spiers, and B.A. Becker. 1994. The effects of diets formulated on an ideal protein basis on growth performance, carcass characteristics, and thermal balance of finishing gilts housed in a hot, diurnal environment. J. Anim. Sci. 72:367-379.

Luttrell, L.M., T. van Biesen, B.E. Hawes, G.J. Della Rocca, D.K. Luttrell, and R.J. Lefkowitz. 1998. Regulation of mitogen-activated protein kinase pathways by catecholamine receptors. Adv Pharmacol 42:466-70.

McConnell, J.C., K.M. Barth, and S.A. Griffin. 1971. Nutrient digestibility and nitrogen metabolism studies at different stages of growth with fat and lean type swine fed two levels of protein. J. Anim. Sci. 32:654-657.

McKeith, F.K., and M. Ellis. 2001. Effects of ractopamine on meat quality. J. Anim. Sci. 79(Suppl.1):239.

McKeith, F.K., E.G. Perkins, P.J. Bechtel, D.J. Jones, and D.H. Mowery. 1990. Effects of ractopamine on the fatty acid composition and cholesterol content of pork longissimus muscle. J. Anim. Sci. 68(Suppl.1):336. (Abstr.)

McKeith, F.K., S.D. Singh, C.R. Stites, and P.J. Bechtel. 1988. Palatability and visual characteristics of hams and loin chops from swine fed ractopamine hydrochloride. J. Anim. Sci. 66(Suppl.1):306. (Abstr.)

McNeel, R.L., and H.J. Mersmann. 1999. Distribution and quantification of beta1, beta2, and beta3-adrenergic receptor subtype transcriptions in porcine tissues. J. Anim. Sci. 77:611-621.

Mersmann, H.J. 1998. Overview of the effects of beta-adrenergic receptor agontists on animal growth including mechanisms of action. J. Anim. Sci. 76:160-172.

Mersmann, H.J. 1989. Poetential mechanisms for repartitioning of growth by beta adrenergic agonists. Pages 337-357 in Animal Growth Regulation. D.R. Campion, G.J. Hausmann, and R.J. Martin (Ed.). Plenum Press, New York.

Metabolic Modifiers. 1994. Page 15. National Academy Press, Washington D.C.

Miller, J.B., E.A. Everitt, T.H. Smith, N.E. Block, and J.A. Dominov. 1993. Cellular and molecular diversity in skeletal muscle development: news from in vitro and in vivo. Bioessays 15:191-196.

Mills, S.E. 2002. Biological basis of the ractopamine response. J. Anim. Sci. 80 (E. Suppl. 2): E28-E32.

Mills, S.E., and C.Y. Liu. 1990. Sensitivity of lipolysis and lipogenesis to dibutyryl-cAMP and beta-adrenergic agonists in swine adipocytes in vitro. J. Anim. Sci. 68:3226-3232.

Mills, S.E., C.Y. Liu, Y. Gu, and A.P. Schinkel. 1990. Effects of ractopamine on adipose tissue metabolism and insulin binding in finishing hogs and interaction with genotype and slaughter weight. Domest. Anim. Endocrinol. 7:251-264.

Mimbs, K.J., T.D. Pringle, M.J. Azain, S.A. Meers, and T.A. Armstrong. 2005. Effects of ractopamine on performance and composition of pigs phenotypically sorted into fat and lean groups. J. Anim. Sci. 83:1361-1369.

Mitchell, A.D., M.B. Soloman, and N.C. Steele. 1990. Response of low and high protein select lines of pigs to the feeding of the beta-adrenergic agent ractopamine. J. Anim. Sci. 68:3226-3232.

Moody, D.E., D.L. Hancock, and D.B. Anderson. 2000. Pheethanolamine repartitioning agents, p. 65-96. In J.P.F. D'Mello, ed. Farm Animal Metabolism and Nutrition. CAB International, Wallinford, Oxon, UK.

Moss, F.P., and C.P. Leblond. 1971. Satellite cells as the source of nuclei in muscle of growing rats. Anat. Rec. 170:421-436.

Murray, R.K., D.K. Granner, P.A. Mayes, and V.W. Rodwell. 1996. Harper's Biochemistry. 24th ed. Appleton and Lange, Connecticut.

Northup, J.K. 1985. Overview of guanine nucleotide regulatory protein system, N_3 and N_i, which regulates adenylate cyclase activity in plasma membranes. In: P. Cohen and M.D. Houslay (Ed.). Molecular mechanisms of trans membrane signaling. Pages 91-116. Elsevier Science Publishing., New York.

Obrock, H.C., P.S. Miller, and A.J. Lewis. 1997. The effects of reducing dietary crude protein concentration on odor in swine facitlites. Univ. Nebraska Swine Rep. p. 14.

Perkins, E.G., F.K. McKeith, D.J. Jones, D.H. Mowrey, S.E. Hill, J. Novakofski, and P.L. O'Conner. 1992. Fatty acid and cholesterol changes in pork longissimus muscle and fat due to ractopamine. J. Food Sci. 57:1266-1268.

Peterla, T.A., and C.G. Scanes. 1990. Effect of beta-adrenergic agonists on lipolysis and lipogenesis by porcine adipose tissues in vitro. J. Anim. Sci. 68:1024-1029.

Pringle, T.D., C.R. Calkins, M. Koohmaraie, and S.J. Jones. 1993. Effects over time of feeding a β-adrenergic agonist to wether lambs on animal performance, muscle growth, endogenous muscle proteinase activity, and meat tenderness. J. Anim. Sci. 71:636-644.

Reeds, P.J. 1989. Regulation of protein turnover. In: D.R. Campion, G.J. Hausman, and R.J. Martin (Ed.) Animal Growth Regulation. P. 183. Plenum Press, New York.

Rehfeldt, C., I. Fiedler, G. Dietl, and K. Ender. 2000. Myogenesis and postnatal skeletal muscle cell growth as influenced by selection. Livestock Prod. Sci. 66:177-188.

Rodbell, Martin. 1980. The role of hormone receptors and GTP-regulatory proteins in membrane transduction. Nature. 284:17-22.

Sainz, R.D., Y.S. Kim, F.R. Dunshea, and R.G. Campbell. 1993. Temporal changes in growth enhancement by ractopamine pigs. Australian Journal of Agriculture Research. 44(Suppl.1):449.

Schinckle, A.P., B.T. Richert, and C.T. Herr. 2002. Variation in the response of multiple genetic populations of pigs to ractopamine. J. Anim. Sci. 80(Suppl.2):E85.

Schultz, E.A. 1974. A quantitative study of satellite cell population in postnatal mouse lumbrical muscle. Anat. Rec. 180:589-596.

See, M.T., T.A. Armstrong, and W.C. Weldon. 2004. Effect of ractopamine feeding program on growth performance and carcass composition in finishing pigs. J. Anim. Sci. 82:2474-2480.

Smith, J.H. 1963. Relation of body size to muscle cell size and number in the chicken. Poult. Sci. 42:283-290.

Spurlock, M.E., J.C. Cusumano, S.Q. Ji, D.B. Anderson, C.K. Smith II, D.L. Hancock and S.E. Mills. 1994. The effect of ractopamine on beta-adrenoceptor density and affinity in porcine adipose and skeletal muscle tissue. J. Anim. Sci. 72:75-80.

Stites, C.R., F.K. McKeith, S.D. Singh, P.J. Bechtel, D.H. Mowrey, and D.J. Jones. 1991. The effect of ractopamine hydrochloride on the carcass cutting yields of finishing swine. J. Anim. Sci. 69:3094-3101.

Strosberg, A.D. 1996. G protein coupled R7G receptors. Cancer Surv. 27:65-83.

Uttaro, B.E., R.O. Ball, P. Dick, W. Rae, G. Vessie, and L.E. Jeremiah. 1993. Effect of ractopamine and sex on growth, carcass characteristics, processing yield, and meat quality characteristics of crossbred swine. J. Anim. Sci. 71:2439-2449.

Watkins, L.E., D.J. Jones, D.H. Mowrey, D.B. Anderson, and E.L. Veenhuizen. 1990. The effect of various levels of ractopamine hydrochloride on the performance and carcass characteristics of finishing swine. J. Anim. Sci. 68:3588-3595.

Weber, T.E., B.T. Richert, M.A. Belury, Y. Gu, K. Enright, and A.P. Schinckel. 2006. Evaluation of the effects of dietary fat, conjugated linoleic acid, and ractopamine on growth performance, pork quality, and fatty acid profiles in genetically lean gilts. J. Anim. Sci. 84:720-732.

Wegner, J., E. Albrecht, I. Fiedler, F. Teuscher, H.J. Papstein, and K. Ender. 2000. Growth and breed-related changes in muscle fiber characteristics in cattle. J. Anim. Sci. 78:1485-1496.

West, H.D., and H.E. Carter. 1938. Synthesis of α-amino-β-hydroxy-n-butyric acids. VI. Preparation of d- and l- allothreonine and nutritive value of the four isomers. J. Biol. Chem. 122:611-617.

Williams, N.H., T.R. Cline, A.P. Schinckel, and D.J. Jones. 1994. The impact of ractopamine, energy intake, and dietary fat on finisher pig growth performance and carcass merit. J. Anim. Sci. 72:3152-3162.

Yang, Y.T., and M.A. McElligott. 1989. Multiple actions of beta-adrenergic agonists on skeletal muscle and adipose tissue. Biochem. J. 261:1-10.

Yen, J.T., H.J. Mersmann, D.A. Hill, and W.G. Pond. 1990. Effects of ractopamine on genetically obese and lean pigs. J. Anim. Sci. 65:3705-3712.

Young, V.R., W.P. Steffee, P.B. Pencharz, J.C. Winterer, and N.S. Scrimshaw. 1975. Total human body protein synthesis in relation to protein requirements at various ages. Nature (Lond.) 253:192-194.

CHAPTER 1

EFFECTS OF RACTOPAMINE HYRODCHLORIDE AND DIETARY PROTEIN ON GROWTH PERFORMANCE AND ULTRASOUND BODY COMPOSITION OF FINISHING SWINE[1]

---

[1]Shook, J.N., M.J. Azain, C.R. Dove, C.S. Talton, C.W. Parks, T.A. Armstrong, and T.D. Pringle. To be submitted to *The Journal of Animal Science.*

ABSTRACT: Four groups (n = 60/group) of crossbred barrows (B) and gilts (G) were used to evaluate the effects of Ractopamine hydrochloride (RAC), protein level, and gender on growth performance and ultrasound derived carcass composition. Within a gender, pigs were assigned to pens (n = 5 pigs/pen) such that initial weight was equalized across treatments. Pens of a given gender (n = 6/group) were then assigned to a 3×2 factorial arrangement with three dietary protein levels [16% CP (16CP), 18% CP (18CP), and 16% CP with crystalline amino acids (Lys, Met, Thr) added to equal the 18% CP (16AA)] and two dietary RAC levels (0 and 10 ppm). Weekly weights and ultrasound measurements were collected during the 28-d finishing period; and at the end of the feeding trial the two average gaining pigs were selected for harvest (n = 96). Data were analyzed using ANOVA for a 3×2×2 arrangement. During wk 1, pigs fed 16AA and 18CP gained more ($P < 0.05$) than pigs fed 16CP; however, diet did not affect ADG after wk 1. There was a trend ($P = 0.06$) for pigs fed 16AA to have a higher overall ADG than pigs fed 16CP. Although diet did not affect ADFI, pigs fed 16AA had higher ($P < 0.05$) 28-d G:F than pigs fed 16CP. Dietary RAC increased ($P = 0.05$) ADG during wk 2 of finishing, and RAC increased ($P = 0.05$) G:F over the 28-d trial. Gender affected ADG in wk 1 ($P = 0.05$) and over the 28-d feeding period ($P = 0.02$) with B gaining faster than G. Barrows also had increased ($P = 0.04$) ADFI in wk 4, but no differences ($P > 0.10$) were found in G:F between genders. Over the course of the study, dietary protein level did not affect ultrasound fat (UBF) accretion; however, pigs fed 16AA and 18CP diets had a faster ($P < 0.01$) accretion of ultrasound LMA (ULM) than 16CP pigs. In RAC-fed pigs, UBF was lower ($P = 0.02$) and ULM was higher ($P < 0.01$) than in control (CTL) pigs.

Collectively these data suggest that RAC supplementation is an effective means of improving carcass composition without negatively impacting growth performance.

Key Words: Ractopamine, Dietary Protein, Performance,

Introduction

Today's health conscious consumer continues to discriminate against fat when purchasing meat at the retail counter. In response to this consumer demand, the swine industry has altered their end product by decreasing carcass fat and increasing carcass muscle while also increasing carcass weight (Stetzer and McKeith, 2003). These changes in carcass composition have occurred through genetic and nutritional improvements as well as through the use of the repartitioning agent, Ractopamine hydrochloride (RAC). Repartitioning agents are becoming widely used in finishing diets of swine and thus it is important to evaluate their impact on animal performance. Paylean®, the trade name for the repartitioning agent RAC (Elanco Animal Health, Greenfield, IN) was approved by the FDA for use in finishing swine diets in 1999. Research has shown that RAC improves live performance in swine by increasing ADG (Stites et al., 1991; He et al., 1993; Dunshea et al., 1998), decreasing ADFI (Crenshaw et al., 1987; Aalhus et al., 1990), and improving G:F (Watkins et al., 1990; He et al., 1993; Dunshea et al., 1998), while simultaneously increasing carcass lean-to-fat ratio (Watkins et al., 1990; Bark et al., 1992).

The increase in lean growth associated with RAC feeding results in a higher protein requirement for RAC-fed pigs which has generally been met through an increase in the crude protein content of swine finishing diets. However, the increased availability of crystalline amino acids may offer an affordable alternative to costly protein sources, like soybean meal. Furthermore, the use of crystalline amino acids to meet the amino acid requirements of RAC-supplemented pigs may result in reduced nitrogen excretion by reducing the amount of excess amino acids in the diet. In this study, emphasis was

placed on evaluating the interaction of ractopamine, a repartitioning agent, protein level, and gender and their overall effectiveness in producing a desirable product for today's health-conscious consumer.

Materials and Methods

Four groups (n = 60/group) of crossbred barrows (**B**) and gilts (**G**) with an initial BW of 80 kg, were selected from The University of Georgia Swine Center. All pigs were from PIC-42 females mated to PIC 280 boars (Pig Improvement Co., Franklin, KY). Within a gender, pigs were assigned to pens (n = 5 pigs/pen) such that initial BW within a pen was equalized across treatments. Pens of a given gender (n = 6/group) were then assigned to a 3 x 2 factorial arrangement with three dietary protein levels [16% CP (**16CP**), 18% CP (**18CP**), and 16% CP with crystalline amino acids (Lys, Met, and Thr) added to equal the 18% CP (**16AA**) and two dietary ractopamine hydrochloride (**RAC**) levels (0 and 10 ppm). Diets were corn-soybean meal based, with RAC being added to the diet at the expense of ground corn (**Table 1**). All pigs had *ad libitum* access to feed and water throughout the 28-d experimental feeding period.

Feed intake, live weight, and ultrasound images for 10^{th} rib fat depth (**UBF**) and loin muscle area (**ULM**) were collected at 7-d intervals. Images were collected by a certified technician using an Aloka 500-V ultrasound unit (Corometrics Medical System, Wallingford, CT) using a 17.2 cm, 3.5 MHz linear probe and interpreted using Beef Information Manager software (version 3.5; Critical Vision Inc., Atlanta, GA). Accretion rates for UBF and ULM were calculated by determining the change in the measurements in a given time period and dividing the change by the number of days during that time period [i.e., overall UBF accretion = (UBF at 28d – UBF at 0d)/ 28d; and wk 1 UBF

accretion = (UBF at 7d – UBF at 0d)/7d]. In addition, the UBF and ULM were used, in combination with live weight, to calculate the expected fat-free lean percentages (FFL) of the pigs (NPPC, 1999). Pounds of FFL were calculated using the following equation: (2.1989 x sex; B = 1, G = 2) - (14.784 x UBF, in) + (4.957 x ULM, in^2) + (0.3312 x BW, lbs). Percent FFL was then calculated by dividing pounds of FFL by predicted carcass weight, assuming a dressing percentage of 74% (NPPC, 1999).

Data were analyzed using GLM mixed model procedures of SAS (SAS Inst. Inc., Cary, NC) for a 3 x 2 x 2 factorial design with the main effects of protein (16CP vs. 18CP vs. 16AA), RAC (0 vs. 10 ppm), and gender (B vs. G). Replicate was not a significant source of variation in this study. Pen was used as the experimental unit for the analysis. Least square means were generated and separated using the LSD procedure when there was a significant ($P \leq 0.05$) *F*-test for a main effect or interaction.

Results

Growth Performance

There were no effects ($P > 0.20$) of protein, RAC, or gender on mean BW at any time during the study. However, as expected, mean BW did increase over time ($P < 0.01$). During the first week on trial, pigs fed 16AA and 18CP had higher ($P = 0.01$) ADG than pigs fed 16CP. However, ADG were similar ($P > 0.50$) during the second, third, and fourth weeks. Due to the greater ADG by pigs fed 16AA and 18CP during week one, there was a trend for pigs fed these two diets to have a higher ($P = 0.06$) overall ADG than those fed 16CP (**Table 1.2**). There were no ($P > 0.30$) RAC inclusion effects on ADG other than an increase ($P = 0.05$) in ADG with RAC inclusion during week two. Overall ADG was not ($P > 0.18$) affected by RAC inclusion in the diet (**Table**

1.2). During week one, barrows had a higher (P = 0.05) ADG than did gilts, but gain across gender was similar during weeks two, three and four, and ended with a higher (P < 0.02) ADG for the overall 28-d feeding period (Table 1.2). Daily feed consumption was not significantly affected by protein level or ractopamine inclusion over the entire 28-d trial. However, barrows showed a slight increase (P = 0.11) in ADFI over the entire 28-d trial, noting a slight increase (P = 0.06) in ADFI during the second week, and a significant increase in ADFI during week four. Over the course of the 28-d feeding trial, gain:feed was significantly affected by protein level, with 16AA fed pigs being more efficient that those fed 16CP, and 18CP fed pigs being intermediate. Overall gain:feed was improved (P = 0.05) by the inclusion of 10 ppm of RAC into the finishing diet.

Fat, Muscle and Fat Free Lean Accretion

As expected, ultrasound fat thickness increased (P < 0.01) over time in pigs fed all three levels of protein as well as in pigs fed 0 and 10 ppm RAC. Over the 28-d feeding period, protein level had no significant affect of 10th rib fat accretion rate (**Table 1.3**). Additionally, protein level had no affect on ultrasound 10th rib fat depth at d 0, 7, 14, 21, or 28 (**Figure 1.1**). However, by the end of the trial, pigs fed 10 ppm RAC were leaner (P = 0.02) than those fed 0 ppm RAC. As expected, ultrasound fat depth was lower (P ≤ 0.04) in pigs fed diets supplemented with RAC on d 7, 14, 21, and 28 when compared to those fed diets with no RAC supplementation (**Figure 1.2**). Additionally, RAC had no effect (P ≥ 0.74) on wk 2, 3, or 4 ultrasound 10th rib backfat accretion rates; yet, during the first week of the trial, RAC-fed pigs deposited less (P = 0.01) fat than pigs fed diets with 0 ppm RAC (**Table 1.3**). Initially there were no differences (P > 0.50) in ultrasound 10th rib fat depth between barrows and gilts and this remained constant throughout the

28-d feeding trial, however at week three and thereafter, there was a tendency ($P \leq 0.09$) for gilts to be leaner (**Figure 1.3**).

Ultrasound LMA was not significantly affected by protein level (**Figure 1.4**), however there was a tendency ($P = 0.07$) for pigs fed 16AA to have larger ULM than those fed 16CP, at d 28 of the feeding period, with 18CP being intermediate (**Figure 1.5**). Additionally, protein level had no significant effect on weekly ULM accretion, however, pigs fed diets containing 16AA and 18CP had greater ($P < 0.01$) overall ULM accretion than pigs fed diets containing 16CP (**Table 1.3**). Ultrasound LMA in RAC-fed pigs was not significantly different than the ULM of pigs fed diets devoid of RAC on d 0, 7, 14, or 21 with the exception of RAC fed pigs possessing a larger ($P = 0.02$) ULM on d 28 (**Figure 1.6**). Additionally, ULM accretion rate was not significantly affected by RAC treatment during wk 1, 2, or 3 (**Table 1.3**). However, RAC-treated pigs showed greater ($P = 0.02$) ULM accretion during wk 4, which led to a significant increase in overall ULM accretion (**Table 1.3**). As expected, ULM did increase ($P < 0.01$) over time in both barrows and gilts (**Figure 1.7**), however ULM accretion rate was not significantly affected by gender over the entire 28-d feeding period with the exception of a greater ($P = 0.04$) ULM accretion in barrows during wk 4 (**Table 1.3**).

As expected, ultrasound predicted FFL percentages (UFFL), calculated from NPPC equations, were increased ($P < 0.01$) over time in all three main effects. However, within the protein treatment main effect there were no significant differences between treatments at any of the weekly measurements (**Figure 1.8**). Improvements in UFFL at week one ($P < 0.01$) and after the fourth ($P < 0.01$) week of the trial were noted, as well as a tendency for there to be an increase ($P = 0.08$) in UFFL at weeks two and three in the

RAC-fed pigs when compared to those consuming diets without RAC (**Figure 1.9**). In addition to the improvement with RAC, there was a noted improvement in UFFL at week three ($P < 0.05$) in gilts versus barrows (**Figure 1.10**).

Discussion

Growth Performance

In this study, ADG tended to be higher as protein level increased, which is consistent with reports by Henry et al., (1992), Cromwell et al., (1993), Friesen et al. (1995), and Cline et al. (2000). However, other studies (Critser et al., 1995; Chen et al., 1999) have reported minor or slightly negative effects on ADG with an increase in the protein content of the finishing diet. Additionally, some researchers have observed a decrease in feed consumption with increased protein level in the feed (Chen et al., 1999), whereas others have noted results similar to those reported in this study, where daily feed consumption what not affected by protein level (Critser et al., 1995; Friesen et al., 1995). Due to an increase in ADG and no change in daily feed intake, there was a significant increase in the efficiency of gain in this study which is consistent with findings reported by Cline et al. (2000), Friesen et al. (1995), Cromwell et al. (1993), and Henry et al. (1992). Nonetheless, Chen et al. (1999) and Crister et al. (1995) reported that increasing protein in swine finishing diets had no influence on feed efficiency.

Average daily gain was not affected by RAC in this study, which is consistent with reports by Mimbs et al. (2005), Aalhus et al. (1990), and Yen et al. (1990). However, a number of other studies (Weber et al. 2006; Xiao et al., 1999; Crome et al., 1996) have reported that RAC improved ADG. Some researchers have seen significant decreases in ADFI in RAC-supplemented pigs (Bark et al., 1992; Yen et al., 1990;

Crenshaw et al., 1987) whereas others have reported no effect of RAC on ADFI (Xiao et al., 1999; He et al., 1993; Stites et al., 1991). In this study, there were no differences in ADFI; however, the slight increase in gains with dietary RAC resulted in improved G:F. Improvements in feed efficiency are a very common observation when feeding Ractopamine hydrochloride to finishing pigs (Weber et al., 2006; Mimbs et al., 2005; He et al., 1993; Bark et al., 1992). However, some studies have reported that efficiency was not affected by feeding 10 ppm RAC (Aalhus et al., 1990; Crenshaw et al., 1987). Reports on RAC-stimulated changes in performance of finishing hogs are variable, and this variability may be due to a number of factors, such as length of supplementation (28 to >35d), level of inclusion in the diet (5 to 20 ppm), and body weight (<80 to >120 kg). The results of growth performance across genders were as expected. Barrows gained faster, consumed more feed, and had similar feed efficiencies when compared to the gilts. These findings are very typical of animal performance comparisons between barrows and gilts.

Fat, Muscle and Fat Free Lean Accretion

Body composition, measured by ultrasound, had a tendency to be different with the three different protein levels by day 28 in this study. Protein level had no impact on fat accretion (Figure 1), however due to the tendency for pigs fed 16AA and 18CP to have larger 28-d LMAs than pigs fed 16CP (Figure 4-a and 4-b), there was also a tendency ($P \leq 0.10$) for these two protein levels to have a greater percentage of calculated UFFL (Figure 7). With nearly a 1.0% improvement in FFL after day 28 in the higher protein rations, carcasses from those animals should produce more income when sold on a FFL value-based grid. These findings are similar to findings presented by Chen et al.

(1999), in that increased protein in finishing swine diets led to an increase in LMA. However, there was also a significant decrease in backfat in that study that was not seen in the present study. As a result of the decrease in backfat accretion and the increase in muscle deposition reported by Chen et al. (1999), it is assumed that there would have been a significant increase in FFL had it been calculated.

In addition to improvement in UFFL seen with the varying protein level, there was a significant improvement to UFFL seen with the dietary inclusion of 10 ppm RAC (Figure 8). This finding was a result of a decrease in fat accretion (Figure 2) coupled with larger LMAs (Figure 5) seen after day 28. The total increase in UFFL (> 1.25%) that was seen in pigs supplemented with RAC over the 28-day feeding period should result in an economic advantage for the dietary inclusion of RAC. Other studies have reported increased muscle accretion (Mimbs et al., 2005; Dunshea et al., 1998) and decreased fat accretion (Mimbs et al., 2005; He et al., 1993) in pigs fed RAC; however accretion in those studies was determined by actual carcass measurements as opposed to realtime ultrasound measurements that were taken in this study. In addition, most of those studies reported a greater change in muscle accretion than in fat accretion.

Even though there was a significant increase in predicted UFFL using acquired ultrasound data, the overall increase in UFFL resulting from RAC inclusion may have been underestimated. In a study by Schinckel et al. (2002), it was found that current industry accepted FFL prediction equations underestimate percentage FFL in pigs fed diets containing ractopamine hydrochloride. It was stated in their study that the ultrasound prediction equation from the National Pork Board, 2000, which is similar to the one used in the present study to predict UFFL, only predicted 50% of the increase in

daily fat free lean mass gain. Acknowledging this finding, it may be more accurate to consider other forms of analysis based on partial dissection or chemical analysis to accurately predict carcass FFL.

It has been commonly accepted that carcasses from gilts have larger LMAs as well as less backfat at the time of harvest and therefore a greater FFL as compared to barrows. This fact was not true when comparing the different genders in the current study. When comparing overall values for UBF and ULMA, there was a trend for barrows to have a greater amount of fat at the 10^{th} rib than gilts at the final ultrasound day, and there were no differences between genders on ULMA at the end of the feeding period. Although these changes in carcass measures might suggest the potential for there to be a trend for greater amounts of UFFL in gilts than in barrows, there were no statistically significant differences.

Although ultrasound is becoming a common tool for predicting animal composition, measurement errors do exist (Houghton and Turlington, 1992). In a study by Smith et al. (1992), it was shown that LMA measurements are the most difficult to accurately measure. In pigs, Moeller and Christian (1998) reported that the error associated with estimating LMA was an underestimation of large LMAs and overestimation of small LMAs, whereas in a study by Perkins et al. (1992) they suggested that ultrasound was slightly more precise for beef cattle with smaller LMAs.

Implications

Increasing the protein content of swine finishing diets improved feed efficiency and average daily gains. This gain is a result of increased muscle accretion and decreased fatness. Additional improvements can be seen with the addition of ractopamine into the

diet. While ractopamine did not significantly impact feed intake in this study, as seen in previous research, it did improve feed efficiency. Ractopamine reduced backfat and increased carcass muscle, resulting in carcasses that would have higher levels of fat-free lean. Based on this study, it can be concluded that higher dietary protein levels in conjunction with ractopamine, results in improvements in performance and carcass leanness which should positively impact the profits from pork production if carcass are sold on a fat-free lean value-based grid.

Literature Cited

Aalhus, J.L., S.D.M. Jones, A.L. Schafer, A.K.W. Tong, W.M. Robertson, J.K. Merrill, and A.C. Murray. 1990. The effect of ractopamine on performance, carcass composition, and meat quality of finishing pigs. Can. J. Anim. Sci. 70:943-952.

Bark, L.J., T.S. Stahly, G.L. Cromwell, and J. Miyat. 1992. Influence of genetic capacity for lean tissue growth on rate and efficiency of tissue accretion in pigs fed ractopamine. J. Anim. Sci. 70:3391-3400.

Chen, H.Y., A.J. Lewis, P.S. Miller, and J.T. Yen. 1999. The effect of excess protein on growth performance and protein metabolism of finishing barrows and gilts. J. Anim. Sci. 77:3238-3247.

Cline, T.R., G.L. Cromwell, T.D. Crenshaw, R.C. Ewan, C.R. Hamilton, A.J. Lewis, D.C. Mahan, and L.L Southern. 2000. Further assessment of the dietary lysine requirements of finishing gilts. J. Anim. Sci. 78:987-992.

Crenshaw, J.D., P.M. Swanteck, M.J. Marchello, R.L. Harrold, R.C. Zimprich, and R.D. Olson. 1987. Effects of phenethanolamine (ractopamine) on swine carcass composition. J. Anim. Sci. 65(Suppl.1):308

Critser, D.J., P.S. Miller, and A.J. Lewis. 1995. The effects of dietary protein concentration on compensatory growth in barrows and gilts. J. Anim. Sci. 73:3376-3383.

Crome, P.K., F.K. McKeith, T.R. Carr, D.J. Jones, D.H. Mowrey, and J.E. Cannon. 1996. Effect of ractopamine on growth performance, carcass composition, and cutting yields of pigs slaughtered at 107 and 125 kilograms. J. Anim. Sci. 74:709-716.

Cromwell, G.L., T.R. Cline, J.D. Crenshaw, T.D. Crenshaw, R.C. Ewan, C.R. Hamilton, A.J. Lewis, D.C. Mahan, E.R. Miller, J.E. Pettigrew, L.F. Tribble, and T.L. Veum. 1993. The dietary protein and(or) lysine requirements of barrows and gilts. J. Anim. Sci. 71:1510-1519.

Dunshea, F.R., R.H. King, P.J. Eason, and R.G. Campbell. 1998. Interrelationships between dietary ractopamine, energy intake, and sex in pigs. Aust. J. Agric. Res. 49:656-574.

Friesen, K.G., J.L. Nelssen, R.D. Goodband, M.D. Tokach, J.A. Unruth, D.H. Kropf, and B.J. Kerr. 1995. The effect of dietary lysine on growth, carcass composition, and lipid metabolism in high-lean gilts fed from 72 to 136 kilograms. J. Anim. Sci. 73:3392-3401.

He, P., F.X. Aherne, J.R. Thompson, A.L. Schaefer, and J.K. Merrill. 1993. Effect of ractopamine on carcass characteristics and joint cartilage soundness in finishing pigs. Can. J. Anim. Sci. 73:169-176.

Henry, Y., Y. Colleaux, B. Seve. 1992. Effects of dietary level of lysine and of level and source of protein on feed intake, growth performance, and plasma amino acid pattern in the finishing pig. J. Anim. Sci. 70:188-195.

Houghton, P.L., L.M. Turlington. 1992. Application of ultrasound for feeding and finishing animals: A review. J. Anim. Sci. 70:930-941.

Moeller, S.J., L.L. Christian. 1998. Evaluation of the accuracy of real-time ultrasonic measurements of backfat and loin muscle area in swine using multiple statistical analysis procedures. J. Anim. Sci. 78:934-942.

Mimbs, K.J., T.D. Pringle, M.J. Azain, S.A. Meers, and T.A. Armstrong. 2005. Effects of ractopamine on performance and composition of pigs phenotypically sorted into fat and lean groups. J. Anim. Sci. 83:1361-1369.

NPPC. 2000. Composition and quality assessment procedures. Natl. Pork Prod. Council, Des Moines, IA.

NPPC. 1999. Pork composition and quality assessment procedures. Natl. Pork Prod. Council, Des Moines, IA.

Perkins, T.L., R.D. Green, K.E. Hamlin. 1992. Evaluation of ultrasonic estimates of carcass fat thickness and longissimus muscle area in beef cattle. J. Anim. Sci. 70:1002-1010.

Schinckel, A.P., C.T. Herr, B.T. Richert, M.E. Einstein. 2003. Evaluation of the magnitude of ractopamine treatment biases when fat-free lean mass is predicted by commonly used equations. Swine Research Report. Perdue Univ. 18-23.

Smith, M.T., J.W. Oltjen, H.G. Dolezal, D.R. Gill, B.D. Behrens. 1992. Evaluation of ultrasound for prediction of carcass fat thickness and longissimus muscle area in feedlot steers. J. Anim. Sci. 70:29-37.

Stetzer, A.J. and F.K. McKeith. 2003. Quantitative strategies and opportunities to improve quality Phase I. Phase I in Benchmarking Value in Pork the Pork Supply Chain. American Meat Science Association, Savoy IL.

Stites, C.R., F.K. McKeith, S.D. Singh, P.J. Bechtel, D.H. Mowrey, and D.J. Jones. 1992. The effect of ractopamine hydrochloride on the carcass cutting yields of finishing swine. J. Anim. Sci. 69:3094-3101.

Watkins, L.E., D.J. Jones, D.H. Mowrey, D.B. Anderson, and E.L. Veenhuizen. 1991. The effect of various levels of ractopamine hydrochloride on the performance and carcass characteristics of finishing swine. J. Anim. Sci. 68:3588-3595.

Weber, T.E., B.T. Richert, M.A. Belury, Y. Gu, K. Enright, and A.P. Schinckel. 2006. Evaluation of the effects of dietary fat, conjugated linoleic acid, and ractopamine on growth performance, pork quality, and fatty acid profiles in genetically lean gilts. J. Anim. Sci. 84:720-732.

Xiao, R.J., S.R. Xu, H.L. Chen. 1999. Effects of ractopamine at different dietary protein levels on growth performance and carcass characteristics in finishing pigs. Anim. Feed Sci. Technol. 79:119-127.

Yen, J.T., H.J. Mersmann, D.A. Hill, and W.G. Pond. 1990. Effects of ractopamine on genetically obese and lean pigs. J. Anim. Sci. 65:3705-3712.

Table 1.1 Diet Composition

	Diet		
	16% CP	18%CP	16% + AA
Ingredients, %			
Corn	75.82	70.88	75.85
Soybean Meal	19.23	24.21	18.85
Fat	2.00	2.00	2.00
Dical Phosphate	0.86	0.88	0.85
Limestone	1.44	1.34	1.43
Salt	0.35	0.35	0.35
Vitamin Premix	0.15	0.15	0.15
Mineral Premix	0.15	0.15	0.15
Lysine	-	-	0.19
Methionine	-	0.04	0.10
Threonine	-	-	0.06
Calculated Analysis			
ME, kcal/kg	3350	3360	3350
Crude Protein	16.0	18.0	16.1
Lysine, %	0.77	0.90	0.90
TSAA, %	0.54	0.63	0.63
Threonine, %	0.58	0.66	0.63
Tryptophan, %	0.19	0.22	0.19
Ca, %	0.80	0.78	0.80
P, Total, %	0.49	0.51	0.49
P, Available, %	0.28	0.29	0.28

* Paylean added a 1 lb/ton in place of corn to result in 10ppm.

Table 1.2. Effects of protein level, ractopamine, and gender on growth performance of finishing hogs

	Diet				RAC			Gender			
Item	16	18	16+AA	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
N	16	16	16		24	24		24	24		
First week (0 to 7 d)											
ADG, kg	1.10[y]	1.34[x]	1.39[x]	0.01	1.27	1.28	0.93	1.19	1.36	0.05	0.07
ADFI, kg	2.79	2.90	3.04	0..38	2.95	2.87	0.59	2.86	2.96	0.49	0.13
G:F, kg	0.40	0.47	0.46	0.06	0.44	0.45	0.72	0.42	0.46	0.11	0.02
Second week (7 to 14 d)											
ADG, kg	1.18	1.17	1.14	0.93	1.09	1.24	0.05	1.12	1.20	0.32	0.07
ADFI, kg	3.25	3.24	3.24	0.99	3.24	3.25	0.96	3.14	3.35	0.06	0.09
G:F, kg	0.36	0.36	0.35	0.95	0.37	0.38	0.07	0.36	0.36	0.99	0.02
Third week (14 to 21 d)											
ADG, kg	1.18	1.21	1.32	0.54	1.25	1.22	0.75	1.22	1.26	0.69	0.09
ADFI, kg	3.20	3.26	3.25	0.93	3.22	3.25	0.83	3.16	3.32	0.26	0.12
G:F, kg	0.37	0.37	0.41	0.51	0.39	0.38	0.52	0.39	0.38	0.77	0.03
Fourth week (21 to 28 d)											
ADG, kg	1.09	1.07	1.18	0.56	1.07	1.16	0.34	1.06	1.19	0.24	0.08
ADFI, kg[a]	3.56	3.47	3.57	0.77	3.56	3.50	0.67	3.40	3.67	0.04	0.11
G:F, kg	0.31	0.30	0.33	0.43	0.30	0.33	0.17	0.31	0.32	0.66	0.02
Overall (0 to 28 d)											
ADG, kg	1.14	1.20	1.26	0.06	1.17	1.22	0.19	1.15	1.25	0.02	0.03
ADFI, kg[b]	3.20	3.22	3.27	0.84	3.24	3.22	0.83	3.14	3.32	0.11	0.10
G:F, kg	0.36[y]	0.37[xy]	0.39[x]	0.04	0.36	0.38	0.05	0.37	0.38	0.26	0.007

[x,y,z] Within a trait and main effect, means with different superscripts differ, (P < 0.05).
There were no significant interactions between diet, rac, or gender

Table 1.3. Effects of protein level, ractopamine, and gender on backfat and muscle accretion

	Diet				RAC			Gender			
Item	16	16+AA	18	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
N	16	16	16		24	24		24	24		
First week (0 to 7 d)											
BFgain, mm	4.32	3.05	2.29	0.53	5.08	1.27	0.01	3.56	2.79	0.54	1.24
LEA gain, cm2	4.52	7.61	6.58	0.11	5.55	6.90	0.24	5.74	6.71	0.39	1.01
Second week (7 to 14 d)											
BFgain, mm	-0.76	1.78	0.76	0.42	0.25	0.76	0.74	0.15	1.02	0.62	1.40
LEA gain, cm2	4.97	5.74	8.06	0.13	6.19	6.26	0.95	6.58	5.87	0.57	1.08
Third week (14 to 21 d)											
BFgain, mm	0.76	-0.10	-1.02	0.64	-0.10	-0.15	0.97	-1.27	1.02	0.15	1.22
LEA gain, cm2	7.03	7.94	6.45	0.62	6.77	7.48	0.56	7.48	6.71	0.54	1.07
Fourth week (21 to 28 d)											
BFgain, mm	5.08	6.86	5.84	0.72	6.10	5.84	0.88	6.35	5.59	0.65	1.60
LEA gain, cm2	5.23	6.58	6.06	0.68	4.58	7.29	0.04	4.58	7.35	0.04	1.10
Overall (0 to 28 d)											
BFgain, mm	9.14	11.68	7.87	0.11	11.43	7.87	0.02	8.89	10.16	0.44	1.30
LEA gain, cm2	21.68^{y}	27.81^{x}	27.10^{x}	< 0.01	23.10	28.00	< 0.01	24.39	26.71	0.14	1.30

^{x,y,} Within a trait and main effect, means with different superscripts differ, (P < 0.05).
There were no significant interactions between diet, rac, or gender

Figure 1.1. The main effect of protein level (16, 16AA, or 18) on ultrasound-measured 10th rib fat depth across the 28-d feeding period.

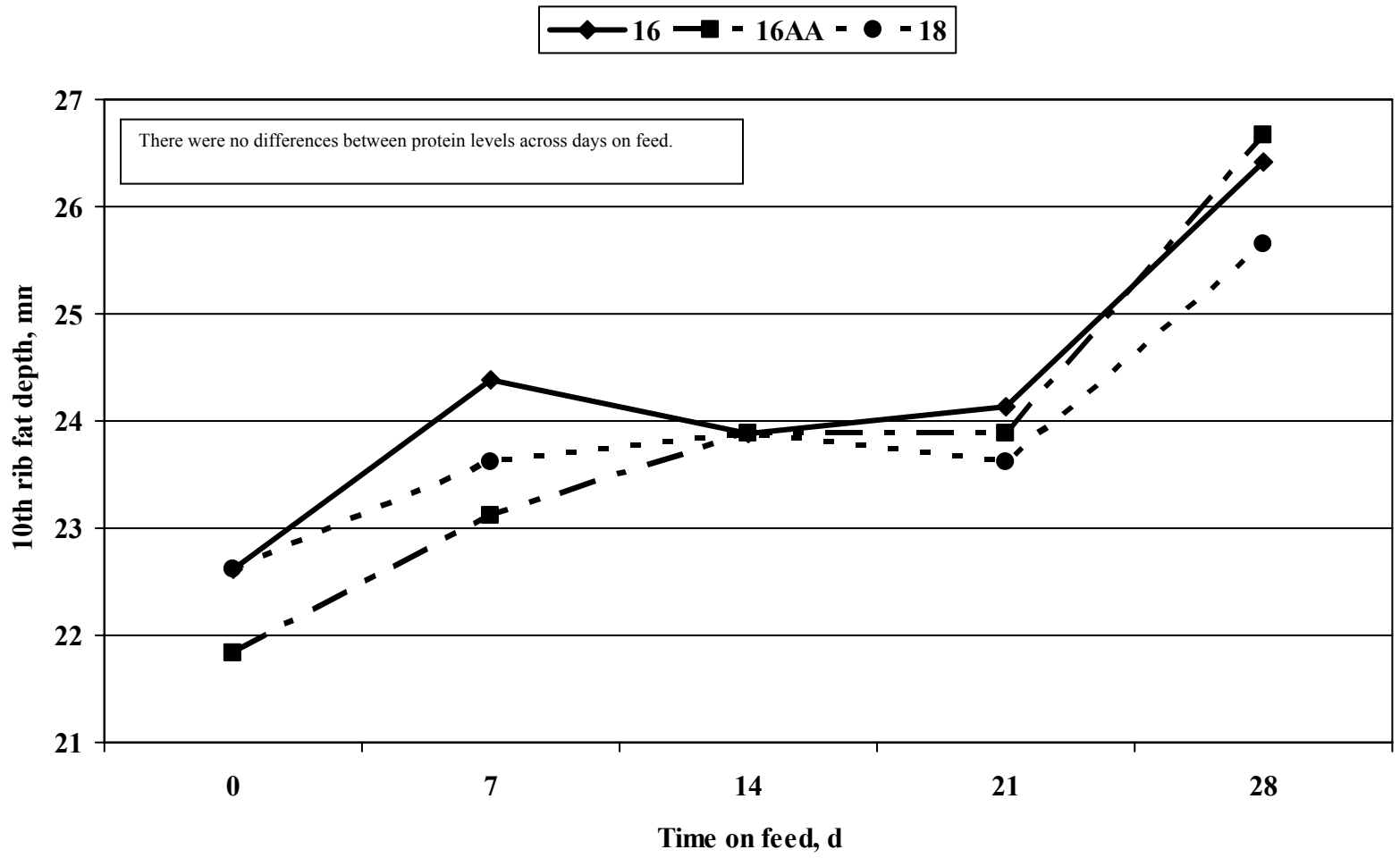


Figure 1.2. The main effect of RAC inclusion level (0 vs. 10 ppm) on ultrasound-measured 10th rib fat depth across the 28-d feeding period.

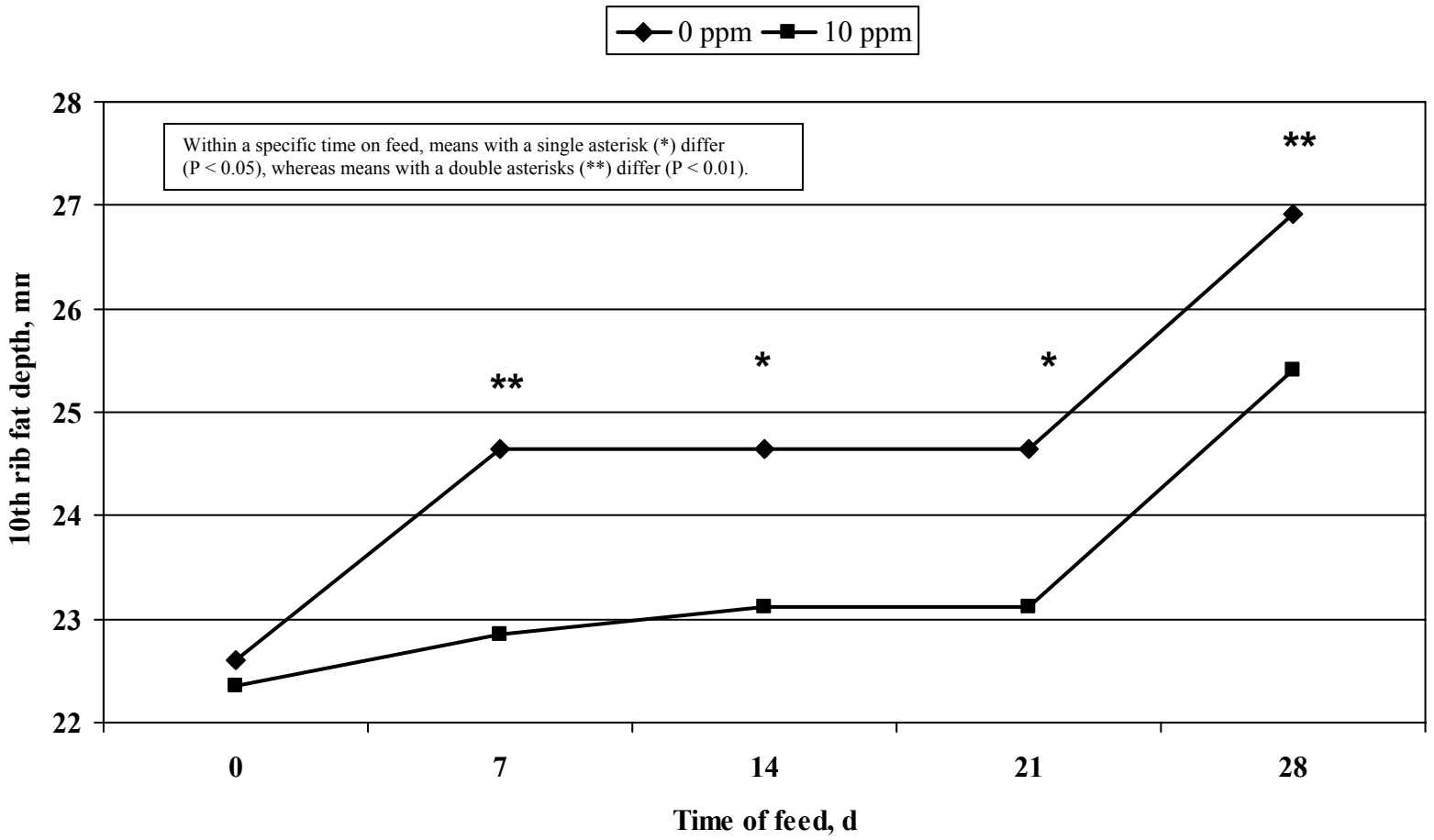


Figure 1.3. The main effect of gender (G vs. B) on ultrasound-measured 10th rib fat depth across the 28-d feeding period.

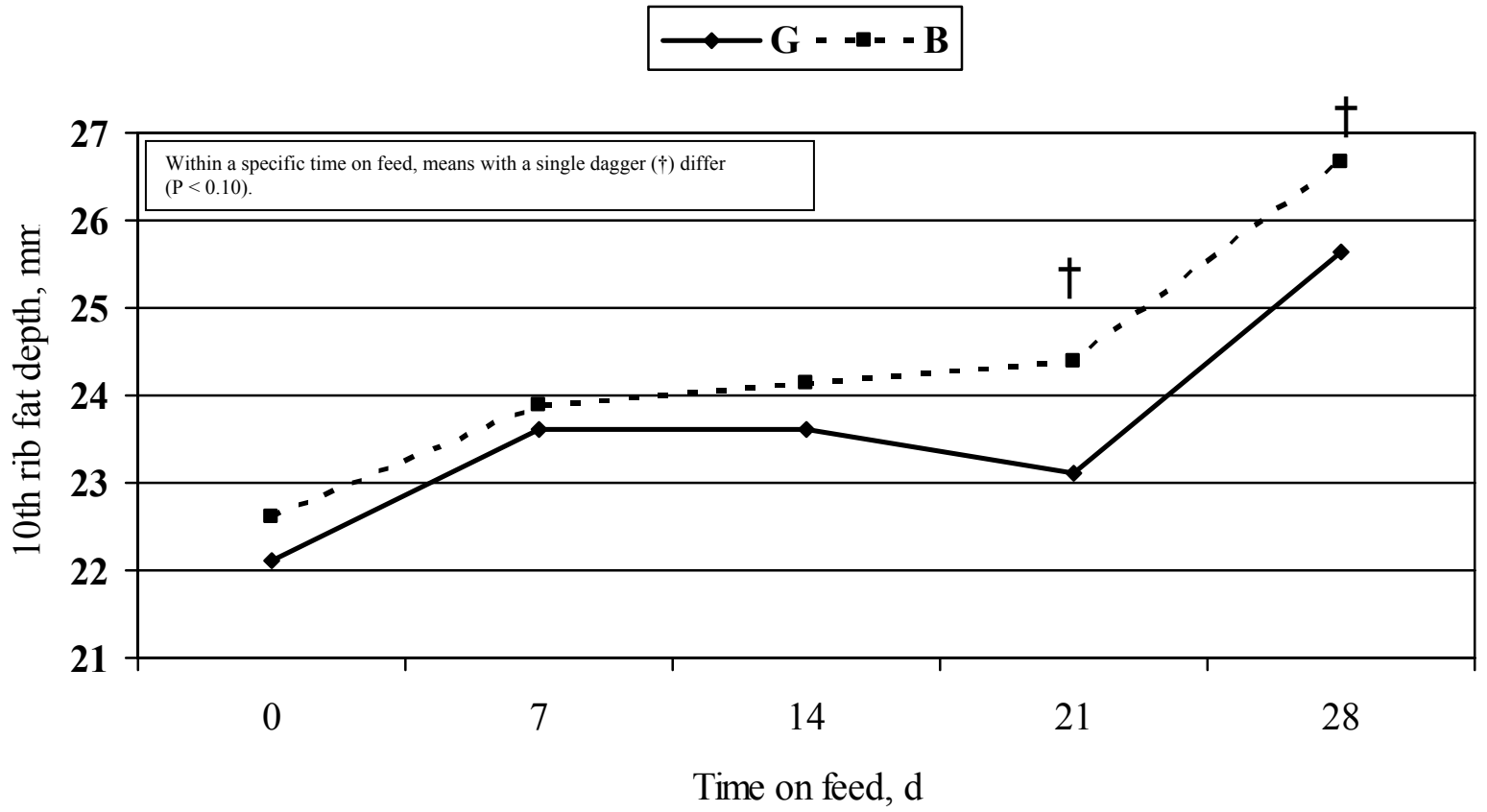


Figure 1.4. The main effect of protein level (16, 16AA, or 18) on ultrasound-measured LM area across the 28-d feeding period.

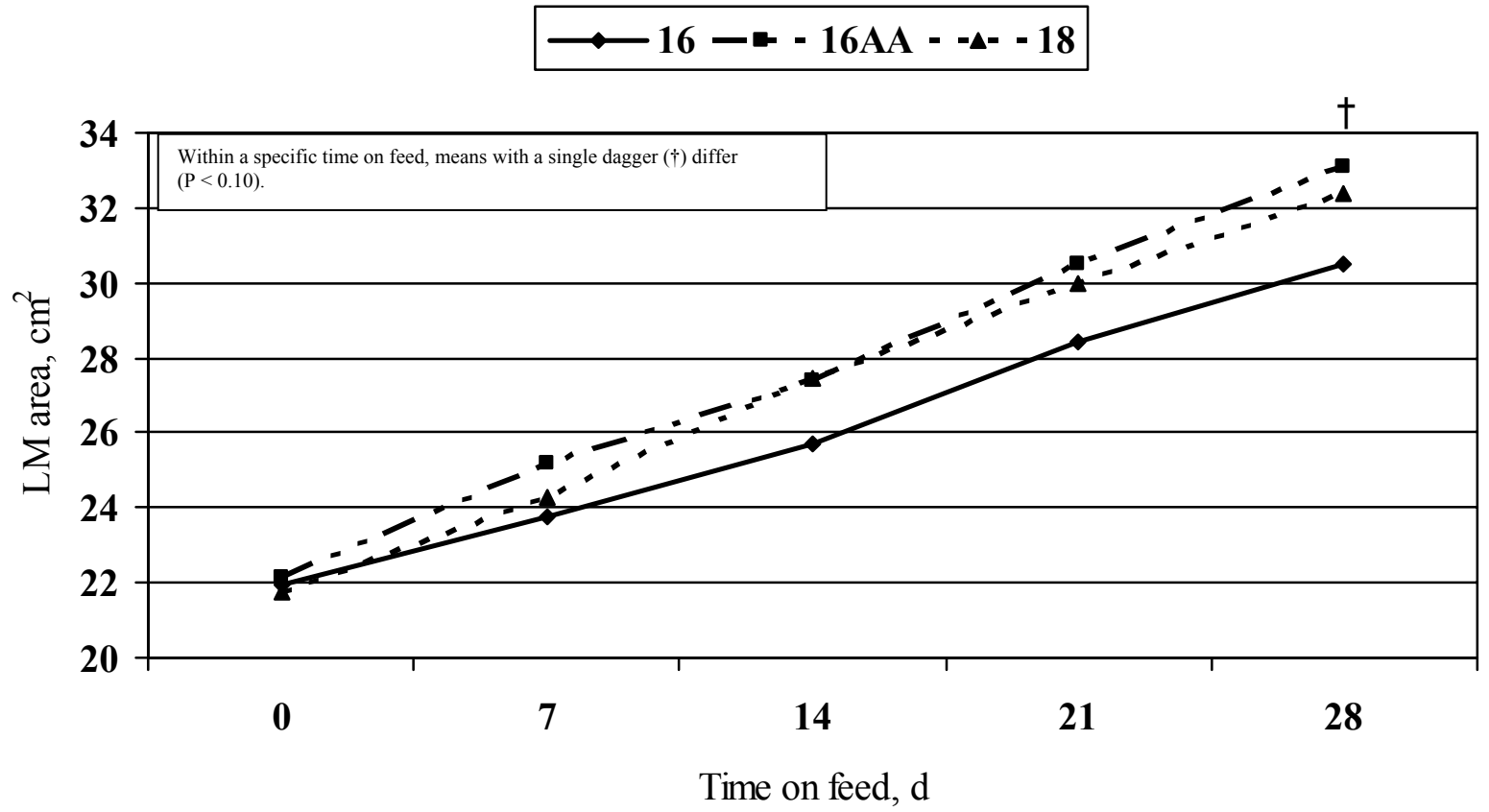


Figure 1.5. The main effect of protein level (16, 16AA, or 18) on ultrasound-measured LM area at day 28.

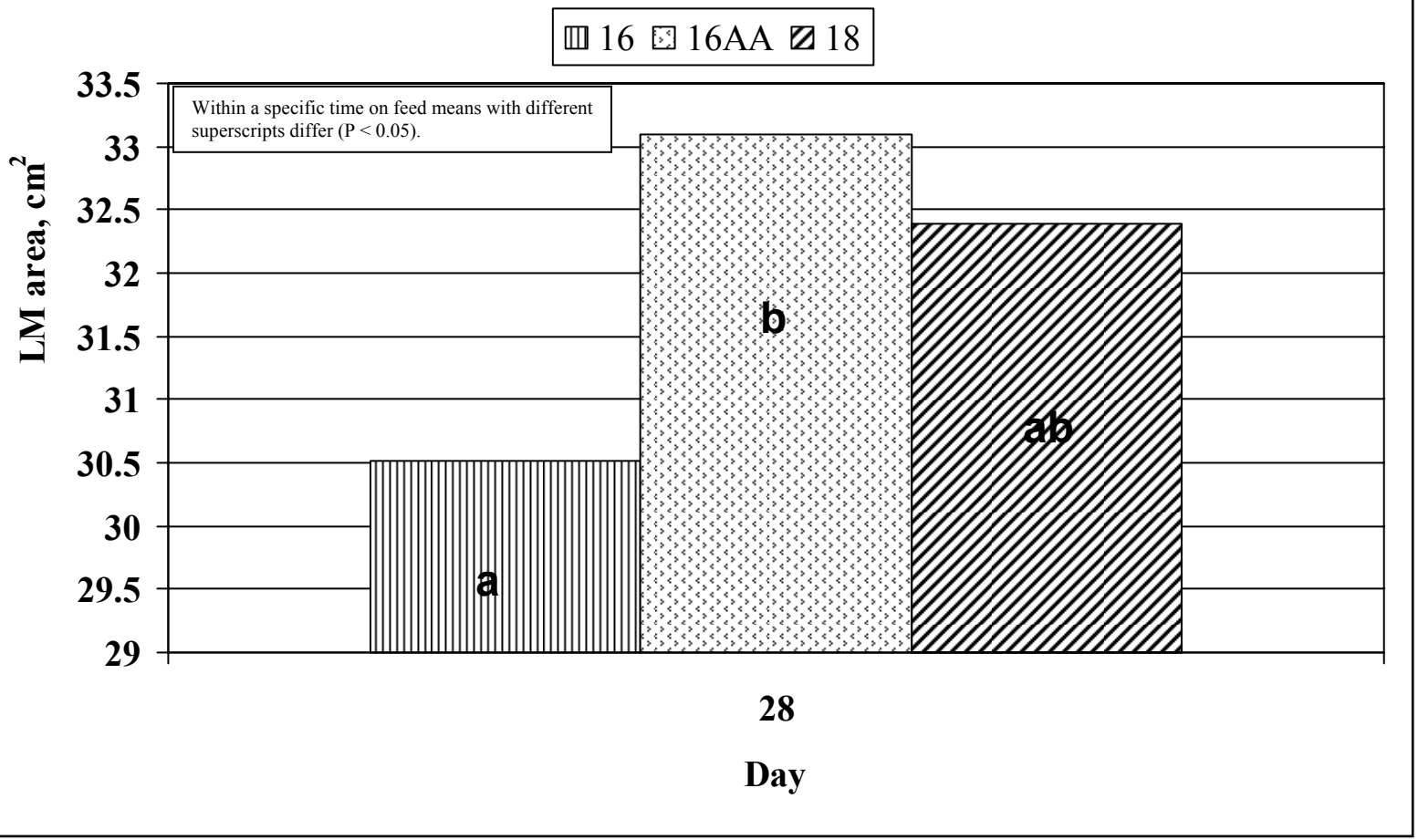


Figure 1.6. The main effect of ractopamine (RAC) inclusion level (0 vs. 10 ppm) on ultrasound-measured LM area across the 28-d feeding period.

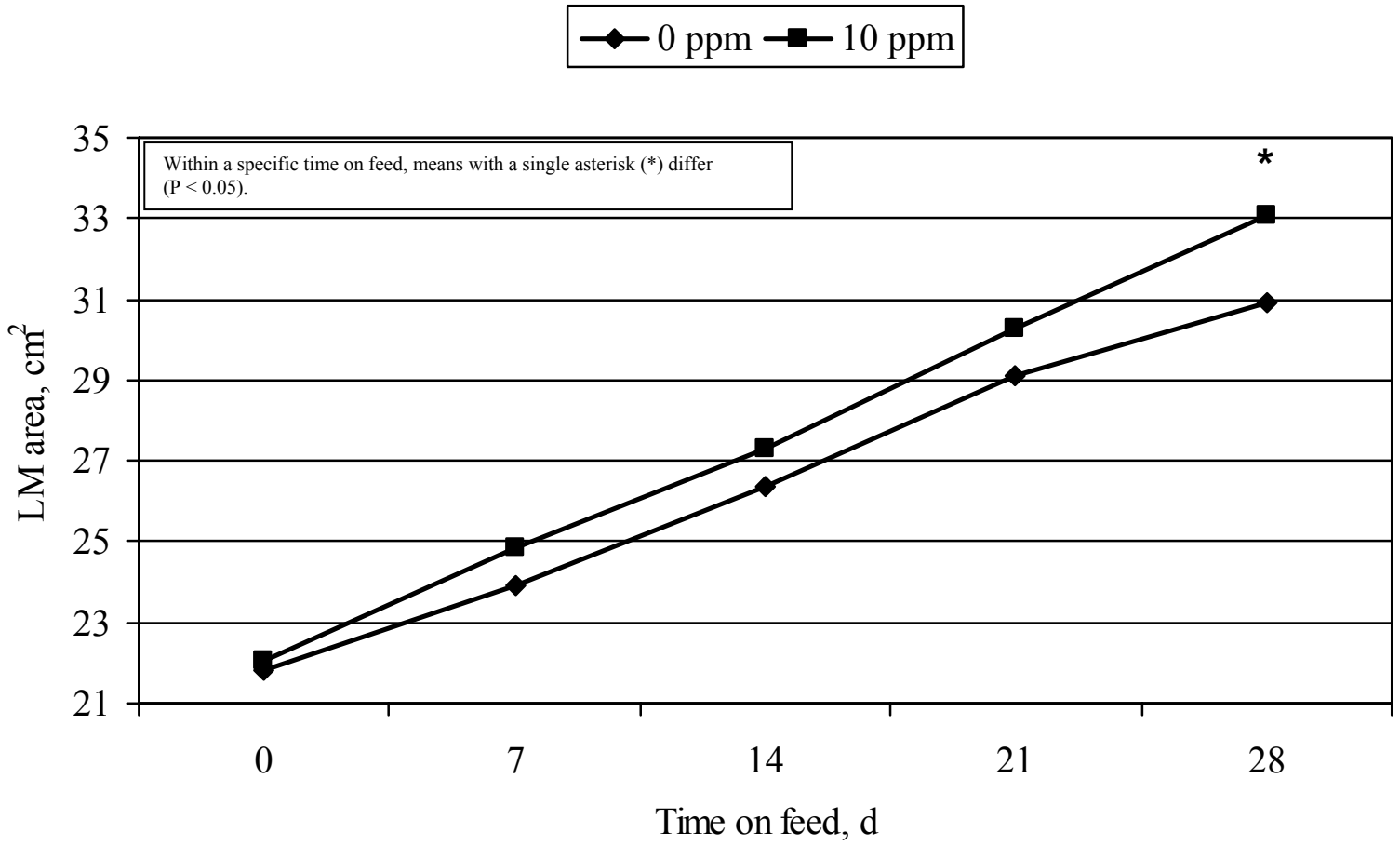


Figure 1.7. The main effect of gender (G vs. B) on ultrasound-measured LM area across the 28-d feeding period.

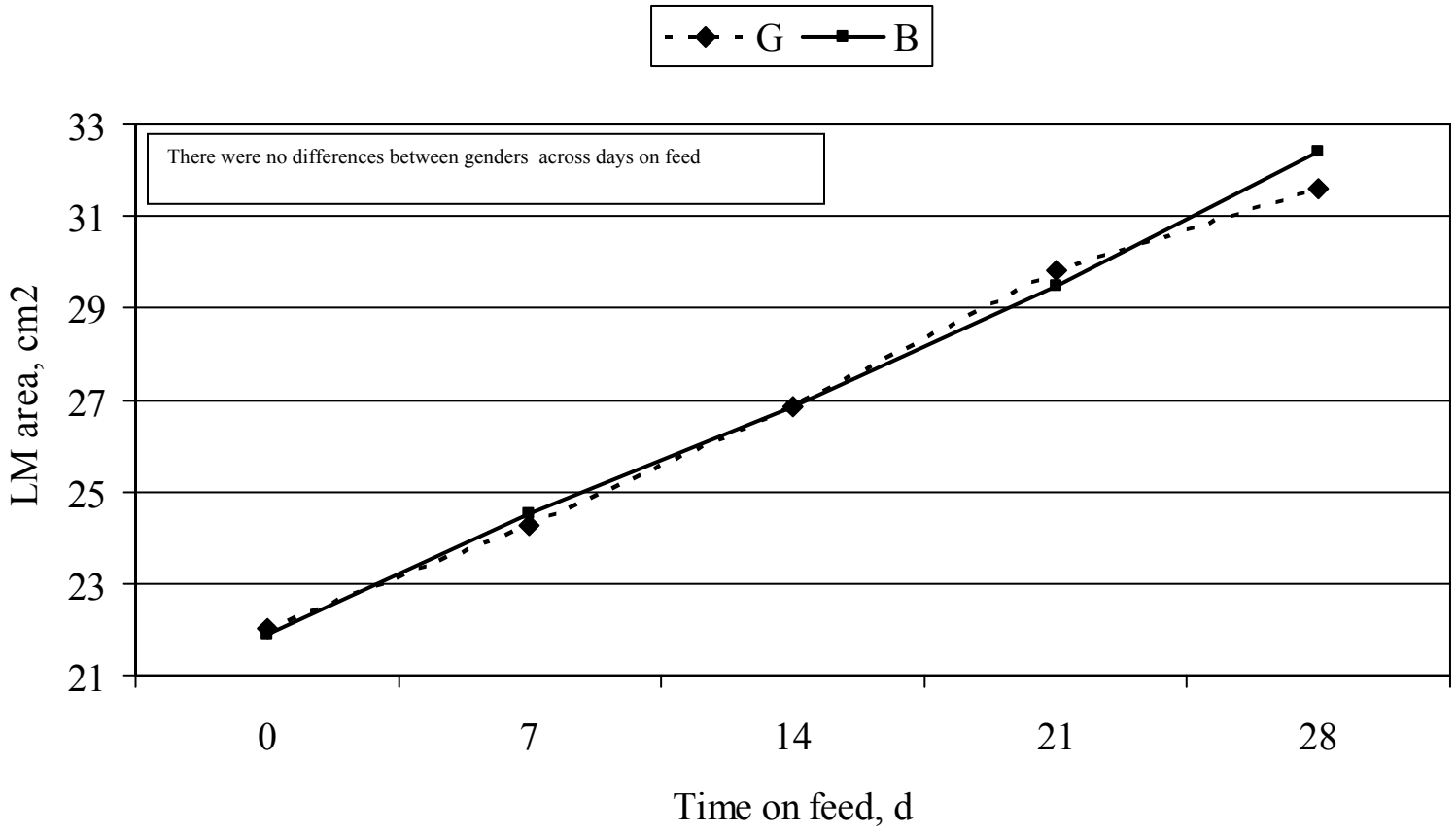


Figure 1.8. The main effect of protein level (16, 16AA, or 18) on percentage fat-free lean across the 28-d feeding period.

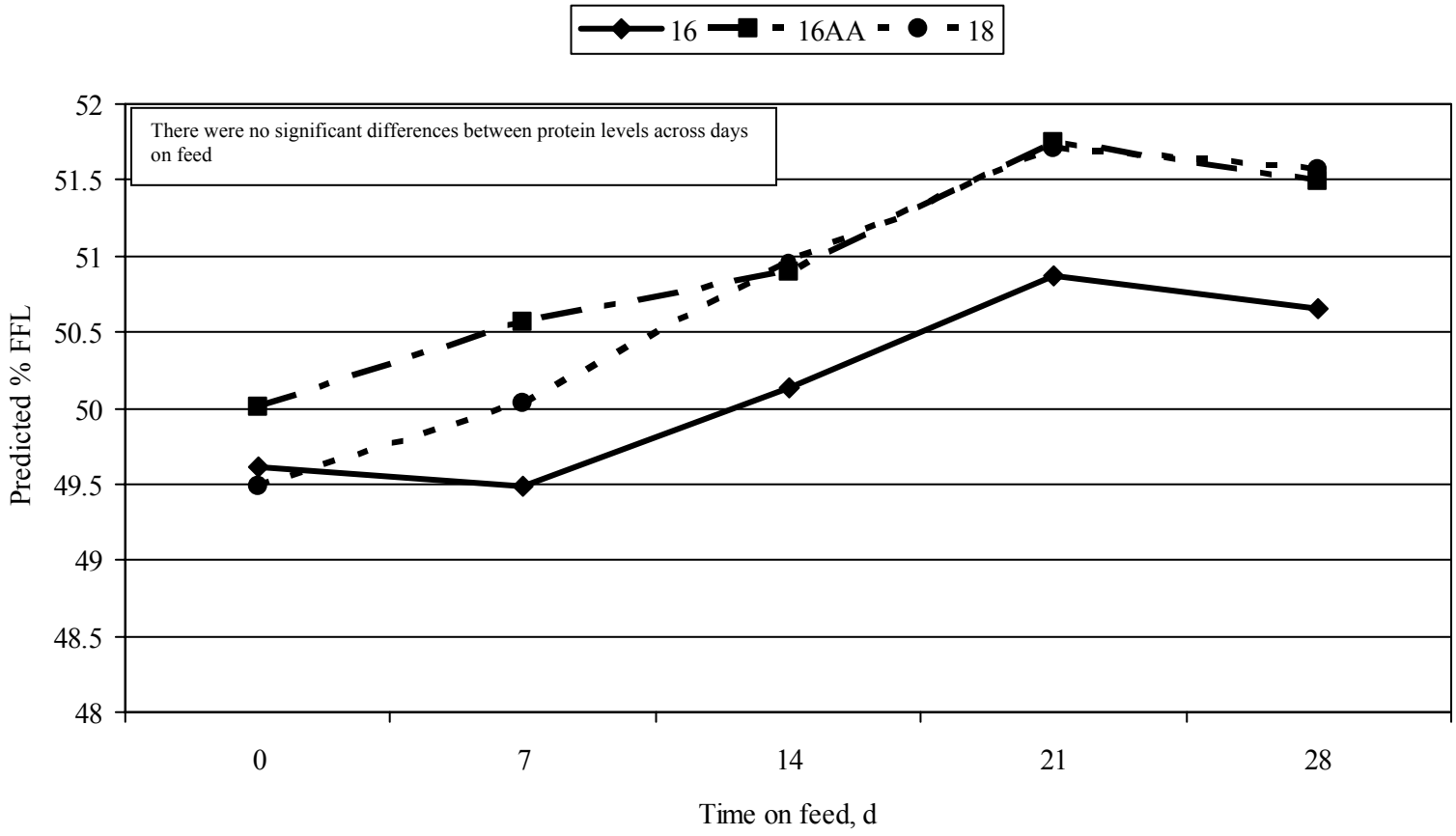


Figure 1.9. The main effect of ractopamine (RAC) inclusion level (0 or 10 ppm) on percentage fat-free lean across the 28-d feeding period.

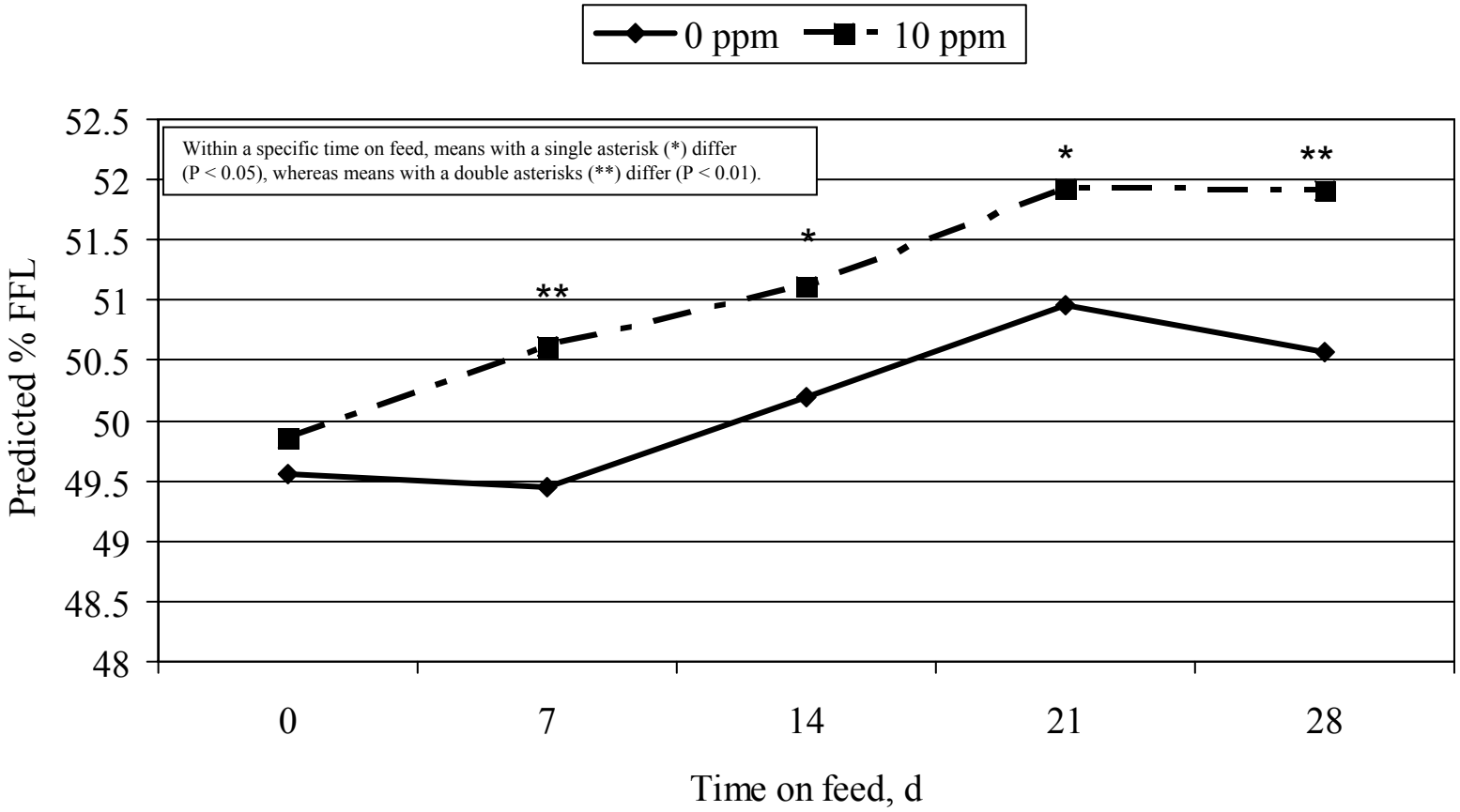
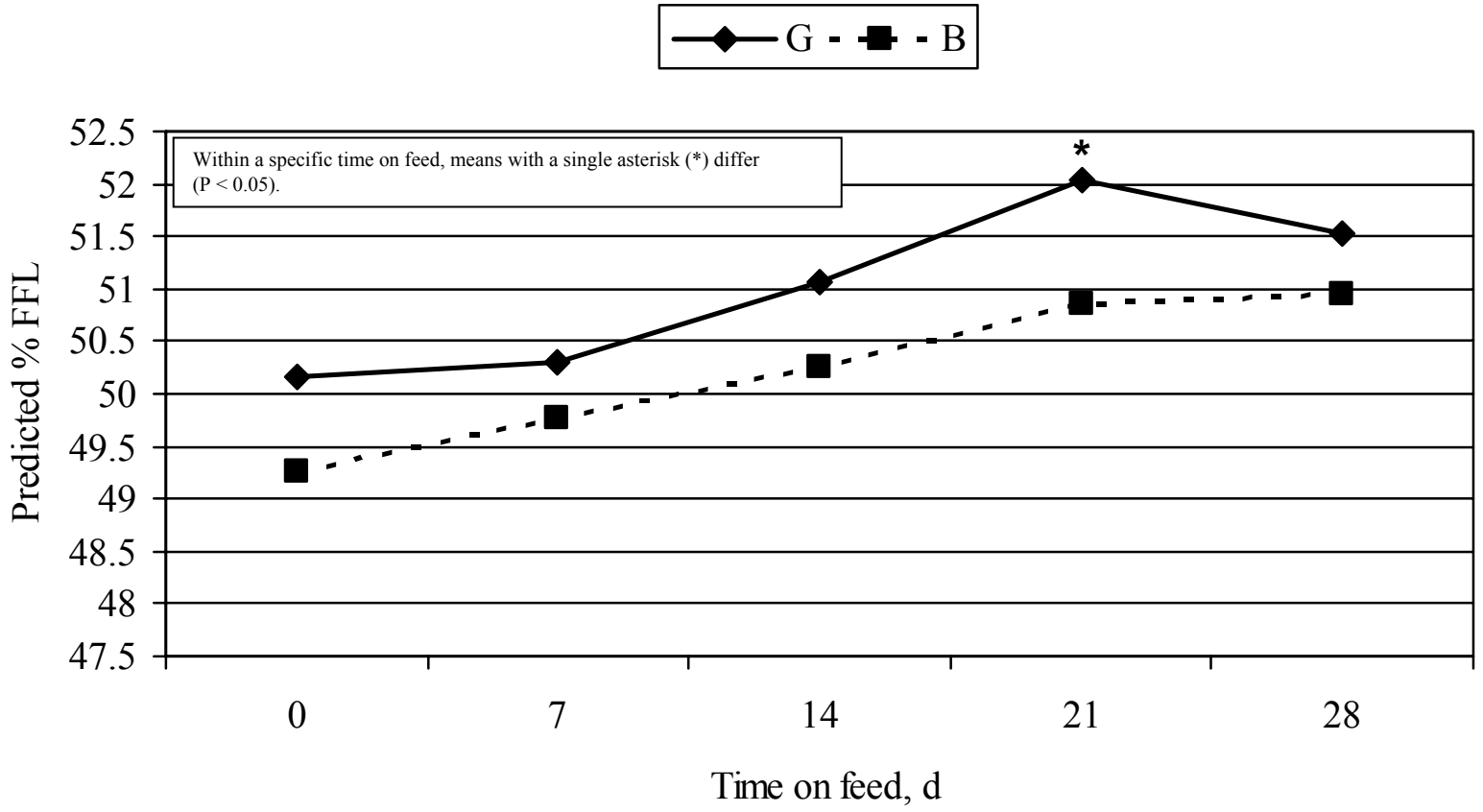


Figure 1.10. The main effect of gender (G vs. B) on percentage fat-free lean across the 28-d feeding period.



CHAPTER 2

EFFECTS OF RACTOPAMINE HYDROCHLORIDE, DIETARY PROTEIN, AND GENDER ON PORK CARCASS COMPOSITION, MEAT QUALITY, BELLY FIRMNESS, AND FATTY ACID COMPOSITION[1]

---

[1]Shook, J.N., M.J. Azain, C.R. Dove, C.S. Talton, C.W. Parks, T.A. Armstrong, and T.D. Pringle. To be submitted to *The Journal of Animal Science.*

ABSTRACT: Four groups (n = 60/group) of crossbred barrows (B) and gilts (G) were used to evaluate the effects of Ractopamine (RAC), protein level, and gender on carcass composition and meat quality traits. Within a gender, pigs were assigned to pens (n = 5 pigs/pen) such that initial weight was equalized across treatments. Pens of a given gender (n = 6/group) were then assigned to a 3 × 2 factorial arrangement with three dietary protein levels [16% CP (16CP), 18% CP (18CP), and 16% CP with crystalline amino acids (Lys, Met, Thr) added to equal the 18% CP (16AA)] and two dietary RAC levels (0 and 10 ppm). The pigs were fed over a 28-d finishing period; and at the end of the feeding trial the two average gaining pigs were selected for harvest (n = 96). After a 24-h chill, carcass composition and quality traits were recorded as well as, belly firmness and fatty acid composition data. Data were analyzed using ANOVA for a 3 × 2 × 2 arrangement. Tenth rib backfat (TRBF) was lower ($P < 0.05$) as well as last lumbar backfat (LLBF) ($P < 0.01$) in pigs fed 18CP than those fed 16CP, with 16AA being intermediate. Likewise, RAC-fed pigs tended to have lower ($P = 0.08$) TRBF than CTL pigs and G had lower ($P < 0.01$) TRBF than B. Pigs fed RAC also had larger ($P = 0.03$) LMAs than CTL pigs. These compositional differences resulted in the pigs fed 16AA and 18CP having higher ($P < 0.05$) FFL than pigs fed 16CP. In addition, RAC-fed pigs and G had higher ($P < 0.01$) FFL than CTL pigs and B, respectively. Loin muscle from RAC-fed pigs was less ($P < 0.01$) red and yellow than LM from CTL pigs. In addition, LM from RAC-fed pigs had a higher ($P = 0.02$) 24-h pH and NPPC marbling score than CTL pigs. There were no significant effects of treatment on LM total lipid; however, RAC-fed pigs, as well as B had a slightly higher total LM lipid percentage ($P< 0.17$) than CTL and B, respectively. There were no differences among treatments for NPPC color or

marbling scores, or 24-h purge loss. Shear force values were greater ($P < 0.01$) for pigs fed 18CP than those fed 16CP, with 16AA being intermediate. Moreover, there were no differences in thaw loss, cooking time, or cooking loss between any of the three test treatments. There were no differences in belly properties across dietary protein level or RAC supplementation; however, B had thicker and firmer ($P = 0.01$) bellies than G. Dietary protein level had no effect on the fatty acid profile of the various fat depots analyzed. However, RAC-supplemented pigs had less saturated in inner subcutaneous fat ($P = 0.02$) and leaf fat ($P = 0.02$). Additionally, gilts had less saturated inner subcutaneous fat ($P < 0.01$), outer subcutaneous fat ($P < 0.01$), and leaf fat ($P < 0.01$) than did barrows. Belly saturation levels were not significantly affected by RAC treatment or gender. Furthermore, there were no significant interactions between the three main effects for the carcass composition, pork quality, belly firmness, or fatty acid composition measures in this study. Collectively these data suggest that RAC supplementation is an effective means of improving carcass composition without negatively impacting carcass quality, regardless of gender or dietary protein level.

Key Words: Ractopamine, Dietary Protein, Pork, Cutability, Pork Quality, Belly Firmness, Fatty Acids, Iodine Value

Introduction

Today's health conscious consumer continues to discriminate against fat when purchasing meat at the retail counter. In response to this consumer demand, the swine industry has altered their endproduct by decreasing carcass fat and increasing carcass muscle while also increasing carcass weight (Stetzer and McKeith, 2003). These changes in carcass composition have occurred through genetic and nutritional improvements as well as through the use of the repartitioning agent, Ractopamine (RAC). Paylean®, the trade name for the repartitioning agent ractopamine hydrochloride (RAC, Elanco Animal Health, Greenfield, IN) was approved by the FDA for use in finishing swine diets in 1999. Research has shown that RAC improves cutability by decreasing fat and increasing lean (Crenshaw et al., 1987; Watkins et al., 1989; Aalhus et at., 1990; Mitchell et al., 1990; Watkins et al., 1990; Bark et al., 1992; Mimbs et al., 2005) while improving or not affecting cacass quality (Aalhus et al., 1990; Watkins et al., 1990; Stites et al., 1991; Uttaro et al., 1993; Sainz et al., 1993b; Crome et al., 1996; McKeith and Ellis, 2001; Mimbs et al., 2005). Additionally, while the increase in cutability due to decreased fat deposition and increased lean is a great benefit to the swine industry, there are concerns that belly thickness and firmness could be affected and negatively impact belly processing traits. Stites et al. (1991) and Uttaro et al. (1993) reported that Paylean supplementation did not affect belly thickness; however, they did not address firmness in terms of Paylean created responses in this research.

The increase in lean growth associated with RAC feeding results in a higher protein requirement for RAC-fed pigs which has generally been met through an increase in the crude protein content of swine finishing diets. However, the increased availability of

crystalline amino acids may offer an affordable alternative to costly protein sources, such as soybean meal. There is, however, limited research focusing on crystalline amino acid use and their effects on carcass composition and quality. In this study, emphasis was placed on evaluating, the interaction of ractopamine, a repartitioning agent, protein level, and gender and their overall effectiveness in producing a desirable, quality product for today's health-conscious consumer with minimal negative effects on industry processing standards.

Materials and Methods

Four groups (n = 60/group) of crossbred barrows (**B**) and gilts (**G**) with an initial BW of 80 kg, were selected from The University of Georgia Swine Center. All pigs were from PIC-42 females mated to PIC 280 boars (Pig Improvement Co., Franklin, KY). Within a gender, pigs were assigned to pens (n = 5pigs/pen) such that initial BW within a pen was equalized across treatments. Pens of a given gender (n = 6/group) were then assigned to a 3x2 factorial arrangement with three dietary protein levels [16% CP (**16CP**), 18% CP (**18CP**), and 16% CP with crystalline amino acids (Lys, Met, and Thr) added to equal the 18% CP (**16AA**) and two dietary ractopamine (**RAC**) levels (0 and 10 ppm). Diets were corn-soybean meal based, with RAC being added to the diet at the expense of ground corn (**Table 2.1**). All pigs had *ad libitum* access to feed and water throughout the 28-d experimental feeding period.

Harvest and Grading:

After finishing, the two average gaining pigs (n = 96) from a pen were transported to The University of Georgia Meat Science and Technology Center, held overnight with access to water, and harvested the following day by standard industry practices. Prior to

placing each carcass in the cooler, hot carcass weights were recorded. After a 24-hour chill period, cold carcass weights were recorded, and then the right sides of the carcasses were ribbed at the 10th rib. The National Pork Producer's Council subjective color, marbling, and firmness scores were recorded. Additional quality measures assessed at the 10th rib included ultimate pH (Cole-Parmer meter—model 05669-00) and colorimeter L*, a*, and b* (Hunter MiniScan XE Plus – 45/0-L). Fat thickness at the first rib, 10th rib, last rib, and last lumbar vertebrae were measured. Tracings of the 10th rib loineye areas were measured using a digitizer pad and Sigma-Scan Scientific Measurement Software, version 3.90 (Jandel Scientific, Corte Madera, CA).

Belly Firmness:

The bellies were collected from the left sides of the carcasses, skinned and trimmed to 46 x 22 cm. Bellies were laid on a flat surface, over-wrapped, and held at -1°C over night. Belly thickness was measured on two points on the ventral and dorsal sides and at the center of the anterior and posterior ends. Belly firmness was evaluated using the belly—bar technique, and firmness was defined as the distance between the anterior and posterior ends when the belly was draped over the bar at the midway point on the dorsal and ventral sides of the belly. The distance between the anterior and posterior end was measured.

Lipid extraction:

Longissimus dorsi samples were collected at the 10th rib from the right sides of the carcasses. From this sample, one 1.27 cm chop was taken and frozen in liquid nitrogen and homogenized. Lipid extractions were prepared in duplicate using the procedure of Folch et al. (1957) with modifications.

Disposable aluminum drying pans were used and dried overnight in a 90°C oven and equilibrated for 5 min in a desiccator. Tissue samples (2.5 g ± 0.1g) were placed into labeled, conical tubes, homogenized with 10 mL of methanol and 5 mL of chloroform (2:1 methanol-chloroform mixture), and allowed to stand for 1 h. Chloroform (5 mL) and 5 mL of 1 M KCl were added to each sample and vortexed. Samples were placed in an ice bath for 5 minutes and then centrifuged at 2,000 x g for 10 min at 0°C. The top layer was aspirated off and discarded without disturbing the meat pellet, and the bottom layer was gently poured into aluminum pans. The samples were dried overnight in the fume hood and then for 30 min at 90°C in a drying oven the next day. Following drying, samples were placed in a desiccator for 5 min. The samples were weighed and percent lipid was calculated ((pan with lipid weight – pan weight)/ sample weight x 100%).

Drip Loss

From the same *longissimus dorsi* sample taken previously, an additional 1.27 cm chop was taken and trimmed to zero outside fat and connective tissue. These samples were then weighed and suspended in a bag to collect any purge loss. The chops were allowed to hang in a 4°C room for 24 h. Upon finishing the 24 h hang period, chops were gently blotted and weighed again, and percent loss was calculated 100 – ((24 h wt/ 0 h wt) *100).

Warner-Bratzler Shear Force:

Warner-Bratzler shear force was completed using the American Meat Science Association guidelines (1995) with modifications. Pork chops (2.54 cm thick) were removed from the same large sample as were the percent lipid and drip loss chops. The chops were trimmed free of external fat, vacuum packaged, aged (7 days), and frozen.

On the afternoon prior to cook, frozen chops were removed from their bags and weighed. The chops were allowed to thaw over night in a 4°C room, afterwhich thawed weights were recorded. Thermocouples were then placed in the approximate geometric center of the chops and they were cooked on Farberware open hearth grills. Chops were turned when the internal temperature reached 35 to 40°C. Chops were cooked to a final endpoint temperature of 71°C, and endpoint temperature, cooking time, and final cooked weights were recorded. Chops were then place in a 4°C cooler overnight. Following the overnight chill, six cores (1.27 cm) from each pork chop were removed parallel to the longitudinal orientation of the muscle fibers. Cores were shorn using an Instron Universal Testing Machine (model 3365) equipped with a Warner-Bratzler head, and the peak shear force was recorded at a crosshead speed of 200mm/min.

Fatty Acid Composition

Fat samples for fatty acid composition analysis were collected from the following depots: 1st rib inner (IF) and outer (OF) subcutaneous fat, 10th rib *longissimus dorsi* (LD), leaf fat (LF), and belly fat (BYF). Subcutaneous fat samples were collected at time of harvest, while belly fat was collected after the belly firmness test, and *longissimus dorsi* fat was taken from the same homogenized samples used for percent lipid determination. All samples were prepared for gas chromatograph (GC) analysis using the procedure of Park and Goins (1994), with modifications.

Approximately 50-100 mg of adipose tissue was weighed into a glass test tube. Added to each sample were 200 µL of methylene chloride, 2 mL of 0.5 N sodium methoxide in methanol, and 1 mL of internal standard (2 mg of C17:0 per mL of methanol). The samples were flushed with nitrogen, vortexed, and heated at 90°C for 30

min. The samples were cooled to room temperature, and 2 mL of 14% boron triflouride in methanol was added to each sample. The samples were flushed with nitrogen, vortexed, and heated at 90°C for 30 min. The samples were then cooled to room temperature. Water (1 mL) and 1 mL of hexane were added to the solution, vortexed, and allowed to separate into two phases. The top layer was then transferred into another test tube. Sodium sulfate anhydrous powder (1 g) was then added to remove any residual water. Samples were stored at 4°C. Prepared samples were transferred into a vial for GC analysis.

Longissimus samples:

The LD samples (1-2 gm) were taken from the LD samples that had already been homogenized for percent lipid determination. Added to each sample were 400 μL of methylene chloride, 4 mL of 0.5 N sodium methoxide in methanol, and 2 mL of internal standard (2 mg of C17:0 per mL of methanol). The samples were flushed with nitrogen, vortexed, and heated at 90°C for 30 min. The samples were cooled to room temperature and 4 mL of 14% boron trifloride in methanol was added to each sample. The samples were flushed with nitrogen, vortexed, and heated at 90°C for 30 min. After cooling to room temperature, 2 mL of water and 2 mL of hexane were added to the solution, vortexed, and then centrifuged at 2000 rpm for 10 min. Following separation, the upper layer was transferred into a new test tube, where sodium sulfate anyhydrous powder was added to remove any residual water. Samples were stored at 4°C. Prepared samples were transferred into a vial for GC analysis.

All samples (adipose and *longissimus*) were analyzed using a Shimadzu Gas Chromatograph GC – 14A with a Supelcowax – 10 fused silica capillary column. Iodine

values were calculated from the gas chromatograph analysis data using the following equation: iodine value = C16:1 (0.95) + C18:1 (0.86) + C18:2 (1.732) + CLA (1.732) + C18:3 (2.616) + C22:1 (0.723) (AOCS, 1998; Gatlin et al., 2002).

Data Analysis:

Data were analyzed using analysis of variance for a 3 x 2 x 2 factorial arrangement with the main effects of diet, ractopamine, and gender. Replicate (n = 4) and replicate interactions were included in the model to remove variation. Animal was the experimental unit used for analysis. Least square means were generated and separated using the least significant difference procedures.

Results:

Carcass Composition:

Neither diet nor RAC had any effect on slaughter, hot carcass, cold carcass weights (**Table 2.2**). In contrast, there was a significant effect of gender on cold carcass weight where barrow carcasses were heavier (P = 0.04) after a 24-hr chill than gilt carcasses. Diet did have a significant impact on 10^{th} rib fat depth (TR) as well as on last lumbar vertebrae fat depth (LLV), in that pigs fed diets containing 16CP were fatter than those fed diets containing 18CP, with animals fed the 16AA diets being intermediate. Furthermore, RAC supplementation had no significant effects on first rib (FR), last rib (LR), and LLV fat depths; however, TR fat depth tended (P = 0.08) to be lower in RAC supplemented pigs. As expected, G had significantly less TR and LR fat (P < 0.01) when compared to barrows. Whereas there was no effect of gender or diet on LMA, ractopamine supplementation did however result in larger LMAs (P = 0.03). With the decrease in TR fat and similar HCW and LMA, there was a significant effect of diet on

predicted fat free lean percentages with 18CP and 16AA being superior ($P < 0.01$) to 16CP. Similarly, RAC supplementation had no effect of HCW, but the significantly larger LMA and lower TR fat, resulted in RAC fed pigs having a significant higher ($P < 0.01$) predicted fat free lean percentage than pigs no RAC. Again as expected, G had a significantly higher ($P < 0.01$) predicted fat free lean percentage than B, due primarily to reductions in TR fat.

Carcass Quality:

Instrumental and subjective quality measures were not significantly affected by any of the dietary protein levels, with the exception of Warner Bratzler shear force (WBSF) value. Shear force values were lower in loin chops from pigs on diets containing 16CP ($P < 0.01$, **Table 2.3**), than those fed diets with 18CP and 16AA. Furthermore, percent longissimus intramuscular fat and belly thickness and firmness were not affected by diet. As reported previously by Carr et al. (2005a), RAC-fed pigs had lower a* ($P < 0.01$) (decreased redness) and b* ($P < 0.01$) (decreased yellowness) values as compared to CTL, while L* (lightness) values were not impacted by RAC supplementation. Ultimate pH was significantly higher ($P = 0.02$) in RAC vs. CTL pigs. For subjective quality evaluation (NPPC, 1999), neither subjective color or firmness scores were significantly affected by RAC inclusion in the diet, In contrast, subjective marbling scores were higher ($P = 0.02$) for RAC-supplemented pigs than CTL pigs and percentage longissimus intramuscular fat was numerically higher with RAC supplementation. Additionally, belly thickness, firmness, and loin WBSF were not impacted by RAC supplementation into the diets. Gender had no affect on subjective or instrumental quality measures ($P > 0.24$). Moreover, there was no impact of gender on

percentage longissimus intramuscular fat or WBSF. However, B had significantly firmer bellies (P = 0.01) than G, while there was no affect of gender on average belly thickness.

Fatty Acid Composition:

Inner Subcutaneous Fat: Dietary treatment had on affected on fatty acid concentration (FAC) of inner subcutaneous fat (ISQ) (**Table 2.4**) or saturation level (**Table 2.9).** Conversely, RAC-fed pigs had higher C18:1 (P = 0.04), CLA (P = 0.02), C20:1 (P < 0.01), and C20:4 (P < 0.01) than non-RAC-fed pigs. Additionally, RAC supplemented pigs lower levels of C16:0 (P = 0.03) and C18:0 (P = 0.01). This resulted in RAC supplemented pigs having a higher (P = 0.02) percentage of monounsaturated fat (MUFA) and a lower percentage of saturated fat (P < 0.01) than CTL:pigs. Furthermore, iodine values (IV) for RAC pigs were greater (P 0.02) than CTLs. Gender had a significant affect on FAC with B having a higher level of C14:0 (P = 0.02), C16:0 (P < 0.01), and C20:1 (P < 0.01) and G having a higher level of C18:2 (P < 0.01), CLA (P < 0.01), and C20:4 (P < 0.01). This resulted in G having a higher (P < 0.01) percentage of polyunsaturated fat (PUFA) and a lower percentage of saturated fat (P < 0.01), thus leading to higher (P < 0.01) IV values for G.

Outer Subcutaneous Fat: Diet and RAC did not affect FAC or saturation levels of outer subcutaneous fat (OSQ) (**Table 2.5 and 2.9)**. However, G did have lower levels of C16:0 (P < 0.01), C16:1 (P = 0.09), and C20:0 (P = 0.02), and higher levels of C18:2 (P < 0.01), C20:2 (P = 0.02), and C20:3 (P = 0.04). These changes led to G having a higher percentage of PUFA (P < 0.01), lower saturation percentage (P < 0.01), and a significantly higher IV (P < 0.01) when compared to OSQ from B.

Leaf Fat: Diet did not affect FAC or saturation levels of leaf fat (**Table 2.6)**. Ractopamine treatment caused a significant decrease in C16:0 (P = 0.01) and C18:0 (P = 0.05), as well as a significant increase in CLA (P = 0.04) and C20:2 (P = 0.02). In addition to these changes there was a trend for RAC-fed pigs to have a higher level of C18:2 (P = 0.07). The afore mentioned changes in fatty acid composition resulted in RAC-supplemented pigs having lower saturation levels (P 0.01) and higher (P = 0.07) PUFA levels than pigs fed no RAC. These changes also led to higher IV values in the leaf fat from RAC vs. CTL pigs (P = 0.02). Gender significantly affected leaf fat C16:0 and C20:1, as G had lower (P < 0.01) levels of these fatty acids and a tendency for lower levels of C14:0 (P = 0.09). Additionally, there was a significant increase in C18:2, C18:3, CLA, C20:2 and C20:4 (P ≤ 0.03) when comparing G vs. B. Fatty acid saturation levels changed with gender, as saturated fatty acids were decreased in G (P = 0.02), and PUFA levels were increased (P < 0.01). These two factors led to increased IV values in G (P < 0.01), when compared to B. (**Table 2.9**).

Longissimus Intramuscular fat: The only fatty acid significantly affected by diet was C16:1, which was higher in pigs fed diets containing 16CP than those fed 18CP or 16AA (**Table 2.7**). All other fatty acids as well as saturation levels were not significantly affected by dietary protein level (P > 0.23). Ractopamine treatment significantly decreased C20:3 and C20:4 (P ≤ 0.03), while RAC increased C20:1 (P = 0.04). Additionally there was a tendency for RAC to decrease C18:2 (P = 0.06) and decrease C20:2 (P = 0.07). Although there were changes in individual fatty acid concentrations, only increased PUFA levels were seen with RAC inclusion (P = 0.05). All other saturation values in the intramuscular fat (MUFA, saturated, and IV) were unaffected by

RAC treatment (**Table 2.9**). Gilts possessed lower levels of C16:0 and C16:1 ($P \leq 0.04$) and higher levels of C20:2 and C20:3 ($P \leq 0.02$) than did B. Gilts also showed a tendency for increased levels of C20:4 ($P = 0.07$). Overall, G had a significant decrease in saturated fatty acids ($P = 0.05$) and had a slightly higher IV value ($P = 0.06$) than B.

Belly Fat: Diet did not significantly affect fatty acid concentration ($P > 0.40$) (**Table 2.8)** in belly fat. While RAC treatment did not significantly affect fatty acid concentration in the belly, RAC-supplemented pigs did tend to have higher levels of C18:2 and C18:3 ($P = 0.09$). The only gender effects on fatty acid were a decrease in C20:0 ($P < 0.01$) and an increase in C20:4 ($P = 0.04$), in G. Furthermore, G had a slightly decreased ($P = 0.09$) C20:1 value. Saturation levels were unaffected across all three main treatments with there being only a slight increase in PUFA in RAC-supplemented pigs ($P = 0.09$).

Discussion:

Carcass Composition:

In the current study, there were no differences in HCW, CCW, dressing percentage or chill loss across dietary protein levels. In a study by Friesen et al. (1995) it was reported that dressing percentage and HCW weights were not affected by increasing protein in the diet. In the current study, 10^{th} rib and last lumbar vertebrae fat depths were significantly decreased with an increase in protein in the diet. This is very similar to findings reported by Cromwell et al. (1993), where 10^{th} rib backfat was linearly decreased in gilts fed increasing levels of protein. These findings may indicate that the protein level (or lysine) required to maximize growth rate and carcass leanness may not have been met.

In studies by Chen et al. (1990) and Friesen et al. (1995) it was reported that LMAs were not affected by an increase in protein level in swine finishing diets. In addition Cromwell et al. (1993) showed that while there was not an overall significant affect of increased protein level on LMA, there was a strong interaction of gender and protein with gilts having larger LMAs than barrows at higher protein levels. In another study by Lopez et al. (1994), it was shown that there was no difference in LMA between diets with different amino acid sources. In the current study, there was no difference in LMA among the three different protein treatments; however pigs fed the diet containing synthetic amino acids had numerically larger LMAs when compared to those from pigs fed diets containing 16CP and 18CP.

With a decrease in 10^{th} rib fat deposition in the higher protein diets, along with numerically larger LMAs, predicted fat free lean (FFL) percentages were found to be higher with higher dietary protein levels. This is similar to the findings of Chen et al. (1999), where protein accretion rates were shown to respond to dietary protein in a quadratic manner.

In the current study, there were no differences in HCW, CCW, dressing percentage or chill loss with RAC supplementation. This is in agreement with previous research which has demonstrated no affect of RAC supplementation on HCW and dressing percentage (Watkins et al., 1990; Bark et al., 1992). However, others have shown an increase in HCW and an improvement in dressing percentage with RAC feeding (Stites et al., 1991; Crome et al., 1996; See et al., 2004).

Many researchers have found that RAC supplementation to finishing hogs decreased carcass backfat (Watkins et al., 1990; Yen et al., 1990; Bark et al., 1992), with

10^{th} rib backfat showing the greatest response (Bark et al., 1992; Crome et al., 1996; Carr et al., 2005b). Alternatively, a few researchers have reported that dietary RAC had no effect on 10^{th} rib fat depth (He et al., 1993; Sainz et al., 1993b; Carr et al., 2005a). As for other backfat measurements, Adeola et al. (1990), Crome et al. (1996), Carr et al. (2005a), and Weber et al. (2006) reported that dietary RAC did not affect last rib fat depth, while Carr et al., (2005b) reported a decrease in last rib fat depth and Crome et al., (1996) reported a decrease in first rib fat depth with RAC inclusion in the diet. Although the backfat measurements were lower at all measured location with RAC supplementation, there were no significant changes in backfat depth in this study.

As expected, LMA increased with the addition of 10 ppm ractopamine hydrochloride to the diet. This finding is consistent with other reports of RAC on 10^{th} rib LMA (Stites et al., 1991; Bark et al., 1992; Crome et al., 1996; Schinckel et al., 2002; Carr et al., 2005a). The increase in muscle has been explained primarily through muscle hypertrophy and the accumulation of muscle protein (Aalhus et al., 1992). Conversely, there are a limited number of studies showing that RAC had no effect on LMA (Sainz et al., 1993b).

Ractopamine hydrochloride inclusion into the diet significantly increased predicted FFL values which agree with findings by Mimbs et al. (2004) and See et al. (2004). The reductions in fat accretion and the fact that lean tissue deposition is more energetically efficient than fat (de Lange et al., 2001) may partially explain why improvements in feed efficiency have been so often observed with RAC feeding.

In this study it was shown that G had less back fat, than B especially at the 10^{th} and last rib fat locations. As has been commonly seen, gilts had numerically higher

LMAs than barrows; however the increase was not significant which agrees with findings from Cromwell et al. (1993), Chen et al. (1999), and See et al. (2004). The differences in carcass leanness and muscling typical for barrows and gilts were observed throughout this study, and resulted in gilts having significantly higher FFL percentage than barrows.

Carcass Quality:

Instrumental (Hunter Lab) color values, as well as objective NPPC color scores were not affected by protein level in the finishing which agrees with the findings of Lopez et al. (1994). Dietary protein level had little effect on NPPC firmness and marbling scores which is consistent with findings reported by Lopez et al. (1994). Additionally, protein level had no effect on LM ultimate pH, drip loss, or percentage intramuscular fat (% IMF).

Core samples of chops from pigs fed 18CP and 16AA required the greatest peak force energy to shear. These data are an indication of decreased tenderness with increasing dietary protein and are similar to the findings of Goerl et al. (1995), who reported that increased crude protein in the diet led to greater peak force and total energy required to shear loin chops. It was suggested by Goerl et al. (1995) that increased shear force may be due to a difference in intramuscular fat between chops from lower dietary protein levels vs. chops from higher protein diets. Another theory by Reeds et al. (1980) and Lobley et al. (1987) suggests that muscle protein turnover may be happening at a greater rate in lower protein diets due to protein deficiency, thus creating increased tenderness. Belly firmness was measured using the "belly flop" test and no differences were observed across the three dietary protein treatments.

Feeding ractopamine did not affect Hunter L* values at the cut surface of the *longissimus dorsi* (LM); however, Hunter a* and b* values for the LM indicated that LM was less red and less yellow in RAC-treated pigs than for the control pigs. These findings agree with the results reported by Uttaro et al. (1993) and Carr et al. (2005a). Lower a* values may be due to a shift of intermediate fibers (Type IIa) to white fibers (Type IIb) (McKeith et al., 1988, 1990). Additionally, Carr et al. (2005a) suggested that lower a* values may indicate lower amounts of oxymyoglobin in the muscle, which could be due to the dilution effect caused by hypertrophy of the muscle fibers. Although instrumental color differences were noted with RAC feeding, objective color scores were not affected.

Ractopamine inclusion into the diet significantly increased ultimate pH, as well as, NPPC marbling scores. Increased ultimate pH, in loin chops from RAC-fed pigs, has been reported by Mimbs et al. (2003) and Carr et al. (2005a). Even though Stites et al. (1994) reported numerically higher pH values for loin chops from pigs receiving RAC, the differences were not statistically significant, similar to the findings of Carr et al. (2005b). A limited number of studies have also shown an increase in NPPC marbling scores (Watkins et al., 1990; Mimbs et al., 2003), while others have reported no change (Carr et al., 2005a; Carr et al., 2005b). Although longissimus intramuscular fat percentage (% IMF) was not significantly increased with RAC feeding, values for RAC-fed pigs were higher than those from control pigs. This is different from data reported by Carr et al. (2005b), in that while % IMF was not significantly affected by RAC feeding, values were numerically lower. Additionally, drip loss values were numerically lower with RAC treatment; however, this difference was not significant. In similar findings,

Carr et al. (2005a) reported that feeding 10 mg/kg and 20 mg/kg RAC resulted in a significant decrease in drip loss percentages. However, in another study Carr et al. (2005b) reported that drip loss percent was slightly higher for RAC-fed pigs as compared to controls.

Warner-Bratzler shear force of the loin was not affected by RAC treatment. The effects seen with RAC supplementation are similar to those reported by Stites et al. (1994) and Mimbs et al. (2003). However, Aalhus et al. (1990), Uttaro et al. (1993), and Carr et al. (2005a, b) found that pigs supplemented with RAC had significantly higher shear force values than controls.

Additionally, there were no observed differences in belly firmness due to RAC treatment. In general, decreases in belly firmness can be attributed to decreases in belly thickness, which can lead to industry rejection due to increased processing difficulties associated with thin, soft bellies. Thus, since average belly thickness was unaffected by RAC treatment, decreases in belly firmness were not expected or seen in this study. These findings are similar to previous reports by Mimbs et al. (2003) and Carr et al. (2005a) where belly firmness was not affected by feeding RAC. However, in another study by Carr et al. (2005b), belly firmness measurements were decreased with RAC supplementation, which would indicate lower-quality bellies.

Instrumental color values across genders in this study are similar to the findings of Latorre et al. (2004) in that gender did not significantly affect color. Ultimate pH, drip loss, NPPC firmness and marbling scores, % IMF, and shear force were likewise not affected by gender. In a study by Latorre et al. (2004), it was reported that B and G have very similar *longissimus* fat and moisture contents, which is similar to our findings.

Fatty Acid Profiles:

The level of fatty acid saturation was unaltered by protein level in the diet. Saturated, MUFA, PUFA, and iodine values (IV) all remained within normal and expected ranges for pork fat from the various depots measured. In addition, none of the individual fatty acid concentrations were affected by protein level, with the exception of C16:1 (palmitoleic acid) levels measured in *longissimus* i.m. fat. Although C16:1 levels decreased with increasing crude protein in the diet, total MUFA levels of i.m. fat from the LMA remained unaffected.

In contrast to the findings associated with increasing dietary crude protein, RAC inclusion was found to greatly affect fatty acid saturation levels in certain fat depots. Ractopamine inclusion had a large affect on saturation levels measured in the inner layer of s.c. fat, removed near the 1st rib. RAC-fed pigs had less saturated fat and more monounsaturated fat in their inner fat layer, which corresponded to a higher IV value in the RAC-fed pigs. The changes in IV values are primarily due to significant increases in C18:1 (oleic acid) and C20:1 (eicosenoic acid) concentration as well as significant decreases in the concentration of C16:0 (palmitic acid) and C18:0 (stearic acid). In contrast to the findings for the inner s.c. fat, there were no RAC affects on outer s.c. fat saturation levels or on individual fatty acid concentrations. These finding are somewhat inconsistent with those reported by Carr et al. (2005b), where it was shown that RAC had no impact on the fatty acid profile or saturation level of s.c. fat collected opposite the 10th rib. However, in that study, the three s.c. fat layers were analyzed together. It is believed that the outer layer of s.c. fat was more mature than the inner layer at the time that the pigs began receiving RAC, thus the effects of RAC feeding would not be expected to

have as great of an impact on this fat depot, which was the case. However, since the inner s.c. fat layer was growing as the RAC was being administered, changes in fatty acid composition would be expected due to the partitioning of nutrients away from fat synthesis and towards muscle protein accretion. The RAC effects on fatty acid composition seen in the inner s.c. fat layer are believed to be due to the increased leanness of the animals that were fed RAC. This is consistent with the findings of Mimbs et al. (2004) who reported that the differences in fatty acid composition of RAC-fed and control pigs were similar to the differences noted in pigs that were phenotypically sorted in lean and fat groups, with inner s.c. fat from the lean and RAC-fed pigs showing similar profiles. This hypothesis is supported in the current study by the comparison of the fatty acid profiles from the leaner gilts and the fatter barrows. In this study, the gilts had lower levels of saturated fatty acids as well as higher PUFA and IV values in both the outer and inner s.c. fat layers. The gender differences were the result of gilts having a significantly higher percentage of C18:2 (linoleic acid), CLA, C20:4 (arachidonic acid) and slightly higher levels of C18:3 (linolenic acid) and C20:2 (eicodadienoic acid), in addition to decreased levels of C14:0 (mysteric acid) and C16:0 (palmitic acid).

In addition to the RAC affects noted in the inner s.c. fat, significant effects on fatty acid saturation levels were noted in leaf fat samples. In this depot, saturation levels decreased while PUFA levels increased in RAC-fed vs. CTL pigs. These changes were again due to increasing levels of C18:2, CLA, and C20:2, as well as decreases in C16:0 and C18:0 and higher IV values for RAC-fed pigs compared to controls. The RAC related changes in leaf fat fatty acid profile are very similar to differences seen between genders, where gilts had lower levels of saturated fat as well as increased levels of PUFA.

As a result of increased IV values in the inner s.c. and leaf fat from RAC-fed pigs, concern about fatty acid saturation levels of belly fat and soft bellies from RAC-fed pigs has arisen. Problems that may arise with bacon from bellies with soft fat include bacon slices sticking together, oily appearances in the package, separation of fat and lean during slicing, and increased oxidation rate (NPPC, 1999). In contrast to the findings for inner s.c. and leaf fat but in agreement with the findings of Mimbs et al. (2004), saturation levels of belly fat, in this trial, were not affected by either RAC feeding or gender. There were trends for increased C18:2 and C18:3 concentrations in RAC-fed pigs versus controls, which led to a trend towards an increase in total PUFA levels. However, when IV values were calculated, there was no RAC effect on IV, and the calculated belly fat IV from RAC-fed pigs was less than 70, which Lea et al. (1970) considers the benchmark for fat to be classified as high quality. For gender effects on belly fat, gilts had lower levels of C20:0 and C20:1 and an increased level of C20:4 compared to barrows; however, these fatty acids comprised such a small proportion of the total fatty acid composition, that gender did not affect overall saturation levels or IV, with calculate IVs remaining under the 70 mg of iodine/100 mg of fat benchmark for both genders.

Although lower PUFA values in intramuscular fat from the LM in RAC-fed pigs were found, due partly to some significant changes in the 20 carbon fatty acids, overall IV values were unaffected by RAC feeding. In contrast, i.m. fat from gilts was less saturated than i.m.fat from barrows and had higher IV, partly due to a reduction in C16:0.

In summary, RAC feeding and gender had much greater effects on the fatty acid profile of several pork fat depots than increased dietary protein, which had little to no effect. Ractopamine-related alterations in fatty acid profiles were similar to the profiles

seen in fat from gilts, in that they were generally less saturated. However, in the one area where lower saturation levels could become a problem, belly fat was not affected by RAC treatment.

Implications

While main effects had little to no negative effect on pork carcass quality, they did however have notable positive effects in regards to carcass composition, quality, and fatty acid composition. Higher protein diets had a positive impact on predicted percent fat-free lean as well as RAC supplementation and gender. In addition to improvements in overall carcass cutability, RAC feeding also improved pork loin color scores and increased NPPC marbling scores. Furthermore, RAC-feeding decreased fattyacid saturation levels in inner s.c. fat, while saturation levels in the belly were not altered. In summary, feeding ractopamine hydrochloride, in the form of Paylean® along with varing levels of protein can be utilized to improve carcass cutability traits as well as pork meat quality attributes in either gender of swine, with little to no negative effects on water holding capacity, marbling, or belly firmness.

Literature Cited

Aalhus, J.L., S.D.M. Jones, A.L. Schafer, A.K.W. Tong, W.M. Robertson, J.K. Merrill, and A.C. Murray. 1990. The effect of ractopamine on performance, carcass composition, and meat quality of finishing pigs. Can. J. Anim. Sci. 70:943-952.

Adeola, O., E.A. Darko, P. He, and L.G. Young. 1990. Manipulation of porcine carcass composition by ractopamine. J. Anim. Sci. 68:3633-3641.

AMSA. 1995. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of fresh meat. National Livestock and Meat Board, Chicago, IL.

AOCC. 1998. Official methods and recommended practices of AOCS. 5th ed. Am. Oil. Chem. Soc., Champaign, IL.

Bark, L.J., T.S. Stahly, G.L. Cromwell, and J. Miyat. 1992. Influence of genetic capacity for lean tissue growth on rate and efficiency of tissue accretion in pigs fed ractopamine. J. Anim. Sci. 70:3391-3400.

Carr, S.N., D.J. Ivers, D.B Anderson, D.J. Jones, D.H. Mowrey, M.B. England, J. Killefer, P.J. Rincker, and F.K. McKeith. 2005a. The effects of ractopamine hydrochloride on lean carcass yields and pork quality characteristics. J. Anim. Sci. 83:2886-2893.

Carr, S.N., P.J. Rincker, J. Killefer, D.H. Baker, M. Ellis, and F.K. McKeith. 2005b. Effects of different cereal grains and ractopamine hydrochloride on performance, carcass characteristics, and fat quality in late-finishing pigs. J. Anim. Sci. 83:223-230.

Chen, H.Y., A.J. Lewis, P.S. Miller, and J.T. Yen. 1999. The effect of excess protein on growth performance and protein metabolism of finishing barrows and gilts. J. Anim. Sci. 77:3238-3247.

Crenshaw, J.D., P.M. Swanteck, M.J. Marchello, R.L. Harrold, R.C. Zimprich, and R.D. Olson. 1987. Effects of phenethanolamine (ractopamine) on swine carcass composition. J. Anim. Sci. 65(Suppl.1):308.

Crome, P.K., F.K. McKeith, T.R. Carr, D.J. Jones, D.H. Mowrey, and J.E. Cannon. 1996. Effect of ractopamine on growth performance, carcass composition, and cutting yields of pigs slaughtered at 107 and 125 kilograms. J. Anim. Sci. 74:709-716.

Cromwell, G.L., T.R. Cline, J.D. Crenshaw, T.D. Crenshaw, R.C. Ewan, C.R. Hamilton, A.J. Lewis, D.C. Mahan, E.R. Miller, J.E. Pettigrew, L.F. Tribble, and T.L. Veum. 1993. The dietary protein and(or) lysine requirements of barrows and gilts. J. Anim. Sci. 71:1510-1519.

de Lange, C.F.M., S.H. Birkett, and P.C.H. Morel. 2001. Protein, fat, and bone tissue growth in swine. Pages 65-81 in Swine Nutrition. 2nd et. A. J. Lewis and L.L. Southern, ed. CRC Press, Boca Raton, FL.

Folch, J., M. Lees, and G.H. Sloane-Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissue. J. Bio. Chem. 226:497-509.

Friesen, K.G., J.L. Nelssen, R.D. Goodband, M.D. Tokach, J.A. Unruth, D.H. Kropf, and B.J. Kerr. 1995. The effect of dietary lysine on growth, carcass composition, and lipid metabolism in high-lean gilts fed from 72 to 136 kilograms. J. Anim. Sci. 73:3392-3401.

Gatlin, L.A., M.T. See, J.A. Hansen, D. Sutton, and J. Odle. 2002. The effects of dietary fat sources, levels, and feeding intervals on pork fatty acid composition. J. Anim. Sci. 80:1606-1615.

Goerl, K.F., S.J. Eilert, R.W. Mandigo, H.Y. Chen, and P.S. Miller. 1995. Pork characteristics as affected by two populations of swine and six crude protein levels. J. Anim. Sci. 73:3621-3626.

Hancock, J.D., E.R. Peo Jr., and A.J. Lewis. 1987. Effects of dietary levels of ractopamine on performance and carcass merit of finishing pigs. J. Anim. Sci. 65(Suppl.1):309.

He, P., F.X. Aherne, J.R. Thompson, A.L. Schaefer, and J.K. Merrill. 1993. Effect of ractopamine on carcass characteristics and joint cartilage soundness in finishing pigs. Can. J. Anim. Sci. 73:169-176.

Latorre, M.A., R. Lazaro, D.G. Valencia, P. Medel, and G.G. Mateos. 2004. The effects of gender and slaughter weight on the growth performance, carcass traits, and meat quality characteristics of heavy pigs. J. Anim. Sci. 82:526-533.

Lea, C.H., P.A.T. Swoboda, and D.P. Gatherum. 1970. A chemical study of soft fat in cross-bred pigs. J. Agric. Sci. (Camb.) 74:1-11.

Lopez, J., R.D. Goodband, G.L. Allee, G.W. Jesse, J.L. Nelssen, M.D. Tokach, D. Spiers, and B.A. Becker. 1994. The effects of diets formulated on an ideal protein basis on growth performance, carcass characteristics, and thermal balance of finishing gilts housed in a hot, diurnal environment. J. Anim. Sci. 72:367-379.

McKeith, F.K., and M. Ellis. 2001. Effects of ractopamine on meat quality. J. Anim. Sci. 79(Suppl.1):239.

McKeith, F.K., E.G. Perkins, P.J. Bechtel, D.J. Jones, and D.H. Mowery. 1990. Effects of ractopamine on the fatty acid composition and cholesterol content of pork longissimus muscle. J. Anim. Sci. 68(Suppl.1):336. (Abstr.)

McKeith, F.K., S.D. Singh, C.R. Stites, and P.J. Bechtel. 1988. Palatability and visual characteristics of hams and loin chops from swine fed ractopamine hydrochloride. J. Anim. Sci. 66(Suppl.1):306. (Abstr.)

Mimbs, K.J., T.D. Pringle, M.J. Azain, S.A. Meers, and T.A. Armstrong. 2005. Effects of ractopamine on performance and composition of pigs phenotypically sorted into fat and lean groups. J. Anim. Sci. 83:1361-1369.

Mimbs, K.J., T.D. Pringle, M.J. Azain, and T.A. Armstrong. 2004. Carcass cutability, quality traits, and belly firmness of Paylean supplemented barrows sorted into prefinishing ultrasound backfat thickness classes. UGA ADSC Dept. Ann. Report. pg. 290.

Mimbs, K.J., T.D. Pringle, M.J. Azain, and T.A. Armstrong 2003. The effects of Paylean on live animal performance, carcass cutability and quality, belly firmness and fatty acid composition of pigs sorted into prefinishing backfat classes using real-time ultrasound. M.S. Thesis, University of Georgia, Athens.

NPPC. 1999. Pork composition and quality assessment procedures. Natl. Pork Prod. Council, Des Moines, IA.

Mitchell, A.D., M.B. Soloman, and N.C. Steele. 1990. Response of low and high protein select lines of pigs to the feeding of the beta-adrenergic agent ractopamine. J. Anim. Sci. 68:3226-3232.

Park, P.W., and R.E. Goins. 1994. In situ preparation of fatty acid methyl esters for analysis of fatty acid composition in foods. J. Food Sci. 59:1262-1266.

Prince, T.J., D.L. Huffman, and P.M. Brown. 1987. Effects of ractopamine on growth and carcass composition of finishing swine. J. Anim. Sci. 65(Suppl.1):309.

Reeds, P.J., A. Cadenhead, M.F. Fuller, G.E. Lobley, and J.D. McDonald. 1980. Protein turnover in growing pigs. The effects of age and food intake. Br. J. Nutr. 43:445-455.

Sainz, R.D., Y.S. Kim, F.R. Dunshea, and R.G. Campbell. 1993. Temporal changes in growth enhancement by ractopamine pigs. Australian Journal of Agriculture Research. 44(Suppl.1):449.

Schinckle, A.P., B.T. Richert, and C.T. Herr. 2002. Variation in the response of multiple genetic populations of pigs to ractopamine. J. Anim. Sci. 80(Suppl.2):E85.

See, M.T., T.A. Armstrong, and W.C. Weldon. 2004. Effect of ractopamine feeding program on growth performance and carcass composition in finishing pigs. J. Anim. Sci. 82:2474-2480.

Stetzer, A.J. and F.K. McKeith. 2003. Quantitative strategies and opportunities to improve quality Phase I. Phase I in Benchmarking Value in Pork the Pork Supply Chain. American Meat Science Association, Savoy IL.

Stites, C.R., F.K. McKeith, S.D. Singh, P.J. Bechtel, D.H. Mowrey, and D.J. Jones. 1993. The effect of ractopamine hydrochloride on the carcass cutting yields of finishing swine. J. Anim. Sci. 69:3094-3101.
1994.

Uttaro, B.E., R.O. Ball, P. Dick, W. Rae, G. Vessie, and L.E. Jeremiah. 1993. Effect of ractopamine and sex on growth, carcass characteristics, processing yield, and meat quality characteristics of crossbred swine. J. Anim. Sci. 71:2439-2449.

Watkins, L.E., D.J. Jones, D.H. Mowrey, D.B. Anderson, and E.L. Veenhuizen. 1990. The effect of various levels of ractopamine hydrochloride on the performance and carcass characteristics of finishing swine. J. Anim. Sci. 68:3588-3595.

Watkins, L.E., D.J. Jones, J.R. Gillespie, and R.D. Olsen. 1989. Effects of ractopamine hydrochloride on the carcass composition of finishing swine – 3 – trial summary. J. Anim. Sci. 67(Suppl.2):104.

Weber, T.E., B.T. Richert, M.A. Belury, Y. Gu, K. Enright, and A.P. Schinckel. 2006. Evaluation of the effects of dietary fat, conjugated linoleic acid, and ractopamine on growth performance, pork quality, and fatty acid profiles in genetically lean gilts. J. Anim. Sci. 84:720-732.

Yen, J.T., H.J. Mersmann, D.A. Hill, and W.G. Pond. 1990. Effects of ractopamine on genetically obese and lean pigs. J. Anim. Sci. 65:3705-3712.

Table 2.1 Diet Composition

	Diet		
	16% CP	18%CP	16% + AA
Ingredients, %			
Corn	75.82	70.88	75.85
Soybean Meal	19.23	24.21	18.85
Fat	2.00	2.00	2.00
Dical Phosphate	0.86	0.88	0.85
Limestone	1.44	1.34	1.43
Salt	0.35	0.35	0.35
Vitamin Premix	0.15	0.15	0.15
Mineral Premix	0.15	0.15	0.15
Lysine	-	-	0.19
Methionine	-	0.04	0.10
Threonine	-	-	0.06
Calculated Analysis			
ME, kcal/kg	3350	3360	3350
Crude Protein	16.0	18.0	16.1
Lysine, %	0.77	0.90	0.90
TSAA, %	0.54	0.63	0.63
Threonine, %	0.58	0.66	0.63
Tryptophan, %	0.19	0.22	0.19
Ca, %	0.80	0.78	0.80
P, Total, %	0.49	0.51	0.49
P, Available, %	0.28	0.29	0.28

* Paylean added a 1 lb/ton in place of corn to result in 10ppm.

Table 2.2. Effects of protein level, ractopamine, and gender on Carcass composition

	Diet				Rac			Gender			
Item	16	18	16+AA	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
n					24	24		24	24		
Live Shrink %	5.55	4.74	4.85	0.34	4.88	5.22	0.48	5.16	4.93	0.64	0.42
Hot Carcass Wt, kg	79.51	78.71	81.17	0.59	79.16	80.43	0.53	78.17	81.42	0.11	1.71
Dressing %	74.85	74.43	74.64	0.67	74.58	74.69	0.78	74.81	74.47	0.37	0.33
Cold Carcass Wt, kg	79.08	78.66	80.54	0.66	78.20	80.65	0.18	77.42	81.44	0.04	1.49
Chill Loss %	2.65	2.11	2.09	0.55	2.45	2.11	0.48	2.54	2.03	0.29	0.40
1st rib bf depth, mm	39.09	37.66	38.47	0.68	38.54	38.27	0.84	37.71	39.10	0.30	1.15
10th rib bf depth, mm	21.16^{y}	19.06^{x}	19.88^{xy}	0.03	20.60	19.46	0.08	18.69	21.38	< 0.01	0.55
last rib bf depth, mm	21.16	19.63	21.09	0.13	20.81	20.44	0.59	19.60	21.65	< 0.01	0.59
last lumbar bf depth, mm [a]	21.66^{y}	18.69^{x}	19.47^{xy}	< 0.01	20.02	19.85	0.82	19.43	20.44	0.18	0.63
loineye area, cm^2	38.06	39.42	41.48	0.12	38.13	41.17	0.03	40.32	38.99	0.31	1.14
% Fat Free Lean	51.16^{y}	52.61^{x}	52.53^{x}	0.01	51.45	52.75	< 0.01	53.08	51.12	< 0.01	0.37

[a] last lumbar bf had a significant effect between trt and diet

^{x,y,z} Within a trait and main effect with different superscripts differ, ($P < 0.05$).

Table 2.3. Effects of protein level, ractopamine, and gender on Carcass Quality

	Diet				Rac			Gender			
Item	16	18	16+AA	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
n	32	32	32		48	48		48	48		
Instrumental Color											
L*	56.27	57.17	57.43	0.55	57.16	56.76	0.66	56.93	56.99	0.95	0.78
a*	9.34	9.17	9.06	0.69	9.61	8.77	< 0.01	9.14	9.24	0.74	0.24
b*	16.86	17.00	16.89	0.84	17.37	16.47	< 0.01	16.9	16.94	0.82	0.18
pH	5.64	5.65	5.62	0.43	5.62	5.66	0.02	5.63	5.64	0.64	0.01
Drip Loss	4.27	4.74	4.79	0.56	4.90	4.30	0.17	4.74	4.46	0.51	0.37
NPPC Scores											
Color[a]	2.66	2.34	2.47	0.13	2.46	2.52	0.62	2.50	2.48	0.87	0.11
Marbling[b]	2.06	1.94	2.00	0.80	1.81	2.19	0.02	1.96	2.04	0.59	0.13
Firmness[c]	2.81	2.69	2.75	0.89	2.67	2.83	0.44	2.63	2.88	0.24	0.18
Avg. Belly Thickness, cm	28.98	28.17	29.15	0.75	28.71	28.82	0.92	27.92	29.61	0.13	0.94
Belly Firmness, cm	21.75	19.44	21.90	0.51	22.52	19.54	0.13	18.46	23.59	0.01	1.64
% IMF Fat	2.79	2.70	2.71	0.89	2.62	2.84	0.17	2.62	2.85	0.15	0.14
Shear Force, kg	3.00[y]	3.58[x]	3.44[x]	< 0.01	3.32	3.36	0.79	3.31	3.37	0.67	0.12

[x,y,z] Within a trait and main effect with different superscripts differ, (P < 0.05).
[a] Scale of 1 to 6; NPPC (1999)
[b] NPPC (1999) estimated % lipid
[c] Scale of 1 to 5; NPPC (1991)

Table 2.4. Effects of protein level, ractopamine, and gender on fatty acid composition of middle subcutaneous fat

	Diet				Rac			Gender			
Item	16	18	16+AA	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
n	32	32	32		48	48		48	48		
C14:0, %	0.94	0.92	0.94	0.77	0.94	0.93	0.55	0.90	0.97	0.02	0.02
C16:0, %	21.55	21.37	21.60	0.75	21.78	21.23	0.03	21.03	21.97	< 0.01	0.22
C16:1, %	2.68	2.52	2.62	0.20	2.59	2.62	0.65	2.61	2.60	0.90	0.06
C18:0, %	13.43	13.86	13.65	0.56	14.07	13.23	0.01	13.40	13.90	0.13	0.28
C18:1, %	42.23	41.95	42.19	0.79	41.75	42.50	0.04	42.28	41.96	0.36	0.30
C18:2, %	16.34	16.50	16.19	0.69	16.11	16.58	0.13	16.90	15.78	< 0.01	0.26
C18:3, %	0.59	0.62	0.59	0.43	0.59	0.61	0.13	0.62	0.58	0.06	0.02
CCLA, %	0.20	0.19	0.18	0.55	0.18	0.20	0.02	0.20	0.18	< 0.01	0.008
C20:0, %	0.20	0.20	0.22	0.51	0.20	0.21	0.58	0.21	0.21	0.67	0.01
C20:1, %	0.92	0.90	0.90	0.66	0.88	0.93	< 0.01	0.88	0.94	< 0.01	0.02
C20:2, %	0.62	0.63	0.61	0.46	0.61	0.63	0.15	0.63	0.60	0.08	0.01
C20:3, %	0.09	0.10	0.09	0.58	0.09	0.10	0.19	0.10	0.09	0.15	0.003
C20:4, %	0.22	0.23	0.23	0.53	0.22	0.24	< 0.01	0.24	0.23	< 0.01	0.007

[x,y,z] Within a trait and main effect with different superscripts differ, (P < 0.05).

Table 2.5. Effects of protein level, ractopamine, and gender on fatty acid composition of outer subcutaneous fat

	Diet				Rac			Gender			
Item	16	18	16AA	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
n	32	32	32		48	48		48	48		
C14:0, %	0.95	0.93	0.95	0.83	0.96	0.93	0.30	0.92	0.96	0.14	0.02
C16:0, %	20.36	20.29	20.39	0.94	20.41	20.29	0.63	19.97	20.73	< 0.01	0.21
C16:1, %[a]	3.05	2.94	2.92	0.27	2.93	3.01	0.29	2.91	3.03	0.09	0.06
C18:0, %	10.31	10.74	10.95	0.11	10.81	10.52	0.25	10.47	10.86	0.12	0.22
C18:1, %	44.87	44.23	44.38	0.58	44.42	44.57	0.79	44.66	44.33	0.53	0.47
C18:2, %	17.39	17.77	17.40	0.60	17.41	17.63	0.53	17.99	17.05	< 0.01	0.30
C18:3, %	0.65	0.66	0.65	0.80	0.66	0.65	0.67	0.66	0.65	0.56	0.02
CCLA, %	0.25	0.26	0.24	0.28	0.24	0.26	0.21	0.26	0.24	0.28	0.01
C20:0, %	0.18	0.17	0.18	0.48	0.18	0.17	0.46	0.17	0.19	0.02	0.007
C20:1, %	0.96	0.94	0.94	0.70	0.94	0.96	0.51	0.94	0.95	0.75	0.03
C20:2, %	0.65	0.63	0.63	0.45	0.64	0.64	0.83	0.66	0.62	0.02	0.01
C20:3, %	0.11	0.12	0.11	0.61	0.11	0.11	0.78	0.12	0.11	0.04	0.003
C20:4, %	0.27	0.31	0.27	0.25	0.29	0.27	0.40	0.29	0.28	0.62	0.02

[x,y,z] Within a trait and main effect with different superscripts differ, (P < 0.05).

[a] C16:1,% had a significant effect between sex and diet

Table 2.6. Effects of protein level, ractopamine, and gender on fatty acid composition of leaf fat

	Diet				Rac			Gender			
Item	16	18	16+AA	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
n	32	32	32		48	48		48	48		
C14:0, %	1.07	1.08	1.06	0.95	1.09	1.06	0.61	1.02	1.12	0.09	0.05
C16:0, %	24.91	24.80	24.82	0.93	25.17	24.51	0.01	24.38	25.30	< 0.01	0.23
C16:1, %	2.37	2.38	2.44	0.88	2.39	2.40	0.99	2.39	2.40	0.98	0.11
C18:0, %	18.03	18.36	18.24	0.75	18.55	17.87	0.05	18.10	13.32	0.54	0.31
C18:1, %	38.11	37.37	37.83	0.50	37.60	37.94	0.51	37.58	37.96	0.45	0.46
C18:2, %	13.27	13.67	13.35	0.78	12.98	13.88	0.07	14.21	12.66	< 0.01	0.44
C18:3, %	0.50	0.52	0.48	0.33	0.48	0.52	0.12	0.53	0.47	< 0.01	0.02
CCLA, %[a]	0.13	0.14	0.14	0.87	0.13	0.14	0.04	0.15	0.13	0.02	0.007
C20:0, %	0.22	0.24	0.25	0.35	0.23	0.24	0.60	0.23	0.25	0.19	0.01
C20:1, %	0.71	0.73	0.71	0.72	0.70	0.73	0.27	0.69	0.74	< 0.01	0.02
C20:2, %	0.41	0.43	0.41	0.40	0.40	0.43	0.02	0.43	0.40	0.03	0.01
C20:3, %	0.07	0.07	0.07	0.42	0.07	0.07	0.09	0.07	0.07	0.65	0.003
C20:4, %	0.20	0.22	0.21	0.58	0.20	0.22	0.29	0.22	0.19	0.02	0.01

[x,y,z] Within a trait and main effect with different superscripts differ, (P < 0.05).

[a] CCLA, % had a significant effect between trt and diet

Table 2.7. Effects of protein level, ractopamine, and gender on fatty acid composition of loin intramuscular fat

	Diet				Rac			Gender			
Item	16	18	16+AA	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
n	32	32	32		48	48		48	48		
C14:0, %	0.67	0.66	0.71	0.9	0.73	0.62	0.22	0.69	0.67	0.73	0.08
C16:0, %	24.25	23.4	23.67	0.23	23.46	24.08	0.14	23.28	24.26	0.02	0.36
C16:1, %[a]	4.03[x]	3.49[y]	3.56[y]	0.02	3.59	3.8	0.19	3.53	3.86	0.04	0.14
C18:0, %	11.09	11.56	11.67	0.34	11.51	11.37	0.66	11.24	11.64	0.23	0.29
C18:1, %[b]	46.34	46.66	46.66	0.93	46.12	46.98	0.29	46.86	46.25	0.44	0.71
C18:2, %	9.83	10.29	10	0.78	10.58	9.5	0.06	10.41	9.66	0.17	0.49
C18:3, %	0.17	0.19	0.17	0.36	0.18	0.17	0.21	0.18	0.18	0.96	0.01
CCLA, %	0.09	0.09	0.09	0.87	0.09	0.1	0.2	0.09	0.09	0.44	0.005
C20:0, %	0.15	0.16	0.15	0.71	0.15	0.15	0.91	0.15	0.16	0.66	0.02
C20:1, %	0.85	0.84	0.81	0.62	0.8	0.87	0.04	0.81	0.85	0.26	0.03
C20:2, %	0.24	0.24	0.25	0.97	0.26	0.23	0.07	0.26	0.23	0.01	0.01
C20:3, %	0.27	0.28	0.27	0.87	0.3	0.25	< 0.01	0.29	0.25	0.02	0.02
C20:4, %	2.03	2.15	2	0.72	2.24	1.89	0.03	2.2	1.92	0.07	0.14

[x,y,z] Within a trait and main effect with different superscripts differ, (P < 0.05).

[a] C16:1, % had a significant effect between gender and diet

Table 2.8. Effects of protein level, ractopamine, and gender on fatty acid composition of the belly

	Diet				Rac			Gender			
Item	16	18	16+AA	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
n	32	32	32		48	48		48	48		
C14:0, %	1.17	1.21	1.16	0.87	1.18	1.18	0.96	1.17	1.19	0.75	0.07
C16:0, %	21.84	22.43	22.14	0.50	22.29	21.98	0.41	22.20	22.07	0.74	0.34
C16:1, %	2.99	2.86	2.85	0.57	2.92	2.88	0.72	2.84	2.96	0.36	0.10
C18:0, %	10.65	11.14	11.17	0.42	11.19	10.78	0.23	11.12	10.85	0.45	0.30
C18:1, %	45.91	45.48	45.97	0.82	46.05	45.53	0.47	45.56	46.02	0.53	0.60
C18:2, %	14.58	14.03	13.9	0.66	13.59	14.74	0.09	14.29	14.04	0.71	0.56
C18:3, %	0.58	0.58	0.55	0.73	0.54	0.60	0.09	0.58	0.56	0.64	0.03
CCLA, %	0.23	0.23	0.24	0.88	0.22	0.24	0.21	0.23	0.23	0.81	0.01
C20:0, %	0.18	0.19	0.18	0.68	0.18	0.18	0.99	0.17	0.19	< 0.01	0.006
C20:1, %[a]	0.94	0.96	0.94	0.87	0.93	0.96	0.37	0.92	0.98	0.09	0.03
C20:2, %	0.55	0.53	0.52	0.51	0.52	0.55	0.12	0.53	0.54	0.63	0.02
C20:3, %	0.10	0.10	0.10	0.92	0.10	0.11	0.15	0.10	0.11	0.30	0.004
C20:4, %	0.27	0.28	0.28	0.89	0.27	0.28	0.69	0.29	0.26	0.04	0.009

[x,y,z] Within a trait and main effect with different superscripts differ, (P < 0.05).

[a] C20:1, % had a significant effect between gender and diet

Table 2.9. Effects of protein level, ractopamine, and gender on fatty acid saturation levels

	Diet				Rac			Gender			
Item	16	18	16+AA	Pr > F	0 ppm	10 ppm	Pr > F	G	B	Pr > F	SEM
n	32	32	32		48	48		48	48		
INNER FAT											
Saturated, %	36.12	36.36	36.40	0.89	36.99	35.59	< 0.01	35.54	37.05	< 0.01	0.43
MUFA, %[b]	45.83	45.37	45.70	0.54	45.22	46.05	0.02	45.77	45.50	0.44	0.30
PUFA, %	17.35	17.20	17.55	0.68	17.10	17.63	0.11	17.97	16.76	< 0.01	0.29
Iodine Value	69.04	69.01	68.67	0.88	68.10	69.71	0.02	70.08	67.73	< 0.01	0.58
OUTER FAT											
Saturated, %	31.80	32.14	32.47	0.45	32.35	31.91	0.31	31.52	32.74	< 0.01	0.38
MUFA, %	48.88	48.11	48.24	0.50	48.29	48.53	0.68	48.51	48.31	0.72	0.51
PUFA, %	18.56	19.00	18.56	0.52	18.61	18.81	0.57	19.19	18.22	0.01	0.32
Iodine Value	73.75	73.80	73.19	0.52	73.29	73.86	0.24	74.50	72.65	< 0.01	0.43
LEAF FAT											
Saturated, %	44.23	44.48	44.36	0.94	45.04	43.67	0.01	43.74	44.98	0.02	0.48
MUFA, %	41.18	40.48	40.98	0.48	40.70	41.06	0.46	40.66	41.10	0.36	0.44
PUFA, %	14.11	14.54	14.18	0.76	13.79	14.76	0.07	15.11	13.45	< 0.01	0.47
Iodine Value	59.55	59.68	59.48	0.98	58.58	60.56	0.02	60.84	58.30	< 0.01	0.73
LOIN INTRAMUSCULAR FAT											
Saturated, %	36.15	35.78	36.19	0.85	35.85	36.23	0.59	35.36	36.72	0.05	0.59
MUFA, %a	51.21	50.99	51.03	0.98	50.51	51.65	0.17	51.20	50.96	0.76	0.73
PUFA, %	12.12	12.71	12.26	0.77	13.08	11.65	0.05	12.88	11.85	0.14	0.62
Iodine Value	61.29	61.91	61.43	0.80	62.02	61.07	0.24	62.31	60.78	0.06	0.71
BELLY FAT											
Saturated, %	33.84	34.96	34.65	0.17	34.85	34.12	0.12	34.66	34.30	0.48	0.62
MUFA, %	49.85	49.30	49.77	0.83	49.90	49.37	0.51	49.33	49.95	0.44	0.67
PUFA, %	15.66	15.11	14.96	0.69	14.63	15.86	0.09	15.39	15.10	0.69	0.60
Iodine Value	69.49	68.03	68.17	0.47	67.73	69.40	0.12	68.54	68.58	0.98	0.90

[x,y,z] Within a trait and main effect with different superscripts differ, (P < 0.05). [b] MUFA, % for inner subcutaneous fat had a significant effect between trt and diet

[a] MUFA, % for loin intramuscular fat had a significant effect between trt and diet

CONCLUSIONS

As evident by the results of this study, ractopamine hydrochloride fed at 10 ppm during the last 28-d of finishing can be expected to improve growth performance and carcass cutability, while decreasing saturation levels in some fat depots and having minimal impacts on meat quality attributes. By feeding ractopamine to finishing swine, daily gains can be improved and pigs can more efficiently utilize feed. This can cut feed costs and make pork production more profitable for pork producers. In addition to the added value to the pork producer, ractopamine created higher-value pork carcasses due to a reduction in overall backfat as well as an increase in carcass muscling. The resulting carcasses from RAC-fed pigs have greater amounts of fat-free lean which correlate to higher returns for pork processors per pound of carcass. Furthermore, RAC feeding, at the level investigated, does little to diminish pork quality as early findings might have suggested. In actuality, RAC created a more consumer desirable lean color, as well as increased objective marbling scores and ultimate pH. Furthermore, the negative effects on shear force that have been reported in previous studies were not found in this study. One of the major concerns with RAC feeding in the pork processing industry pertains to belly thickness and firmness; however results from this study showed no negative effects of dietary RAC on belly thickness or firmness. Finally, ractopamine increased iodine values in several fat depots including inner subcutaneous fat and leaf fat. Increased iodine values indicate higher levels of unsaturated fatty acids in the fat. Increased iodine

values can become problematic in pork bellies, because bellies that have a higher proportion of unsaturated fat can become soft and oily leading to processing difficulties. However, in this study RAC feeding did not increase unsaturated fatty acid levels in the belly as it did in leaf and inner subcutaneous fat. Belly fat remained high quality as indicated by IV values below 70 mg of iodine/100mg of fat. Thus, results from this study do not validate concerns about the impact of RAC on belly processing characteristics.

With regards to protein level, higher protein levels led to increased live pig performance as well as an increase in carcass lean. Pigs fed the higher levels of protein would be more profitable for both the pork producer and processor, as these pigs would yield carcasses with greater percentages of fat free lean. In addition to the value added due to increased rate of gain and efficiency of lean production, there were no negative effects of protein level on carcass quality. Additionally, protein did little to change fatty acid profiles of the sampled fat depots.

Gender played a significant role in several growth performance traits as well as several carcass traits. However, these differences were expected, as it is common for barrows to consume greater amounts of feed and gain at a greater rate than gilts. Moreover, the carcass leanness advantages found in gilts were expected, as it is well documented that gilts remain leaner than barrows at harvest. In regards to pork quality, minimal differences were found due to gender. Furthermore, fat from gilts was less saturated than that from barrows, especially in the inner and outer subcutaneous fat as well as in the leaf fat. This was due primarily to increased levels of polyunsaturated fatty acids found in fat tissue from gilts.

In conclusion, although the main effects in the study impacted growth performance, carcass cutability, carcass quality, belly firmness and thickness, and fatty acid profiles, there were no significant interactions among the main effect for any of the measured traits. Thus, it can be concluded from this study, that ractopamine inclusion into finishing swine diets is a beneficial practice in producing high quality pork at an economical rate, regardless of gender or dietary protein level fed during finishing.