THESIS

THE EFFECT OF CRUDE PROTEIN WITHDRAWAL AND THE USE OF β – AGONISTS ON FEEDLOT PERFORMANCE, CARCASS MERIT, AND THEORETICAL NITROGEN RETENTION AND EXCRETION FOR HEAVY YEARLING STEERS

Submitted by

Ryan Kenneth Peterson

Department of Animal Sciences

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Master's Committee:

Advisor: John J. Wagner

Terry E. Engle
Robert J. Callan

ABSTRACT

THE EFFECT OF CRUDE PROTEIN WITHDRAWAL AND THE USE OF β – AGONISTS ON FEEDLOT PERFORMANCE, CARCASS MERIT, AND THEORETICAL NITROGEN RETENTION AND EXCRETION FOR HEAVY YEARLING STEERS

Eight hundred and sixty-four crossbred yearling steers were used in a 3 x 4 factorial experiment to study the effects of β – agonist (BA) administration and crude protein (CP) withdrawal during the last 28 d on feed. Three BA treatments were evaluated: no BA, 200 mg Optaflexx (OPT) per head daily for 28 d, and 75 mg Zilmax (ZIL; 7.56 g/ton DM basis) per head daily for 20 d. The 4 CP withdrawal treatments included: 1) 13.5% CP, 3.5% crude protein equivalent (CPE) from non-protein nitrogen (NPN) from d 0 through slaughter (13.5/3.5); 2) 13.5/3.5 until 28 d remained on feed followed by 12.5% CP, 3.5% CPE from NPN (12.5/3.5); 3) 13.5/3.5 until 28 d remained on feed followed by 12.5% CP, 2.5% CPE from NPN (12.5/2.5); and 4) 13.5/3.5 until 28 d remained on feed followed by 11.5% CP, 1.5% CPE from NPN (11.5/1.5). There were no interactions ($P > 0.32$) between BA and CP withdrawal treatment; therefore, only main effects are discussed. Average slaughter weights and ADG were greater ($P < 0.01$) for steers treated with BA as compared with control steers. There were no differences between the slaughter weights and ADG for the OPT versus the ZIL steers. Beta-agonist treatment had no effect on daily dry matter intake. Feed-to-gain

ratio was improved by 25% for steers fed BA during the final 28 d as compared with controls. More than a 35% improvement ($P < 0.001$) in gain-to-feed ratio (G:F) for the final 28 d was observed for steers fed BA as compared with controls. Differences between OPT and ZIL were not significant. Net energy recovery was increased 19% during the final 28 d on feed for steers fed BA as compared with controls. Least squares means for HCW, adjusted for live weight at treatment initiation, was 9.21 kg heavier ($P < 0.01$) for ZIL steers as compared with controls. The advantage ($P < 0.05$) in HCW for ZIL as compared with OPT was 5.81 kg. Although not statistically significant, the numerical advantage in HCW for OPT as compared with controls was 3.4 kg. Dressing percentage was increased for steers fed ZIL versus control (64.4 versus 63.4%, $P < 0.001$) and OPT ($P < 0.01$) but not increased for OPT versus control (63.2 versus 63.4%; $P = 0.67$). No BA treatment differences were observed for fat depth measured at the 12th rib. Ribeye area for control carcasses (avg = 32.87 cm^2) was lower ($P < 0.06$) than OPT (avg = 33.53 cm^2) which was in turn lower ($P < 0.01$) than ZIL (avg = 34.59 cm^2). Kidney, pelvic, and heart fat was lower for ZIL as compared with control ($P < 0.05$) or OPT ($P < 0.10$). Yield grades calculated from carcass measurements were similar for OPT and ZIL (3.01 versus 2.97), and both were reduced ($P < 0.05$) as compared with control (avg = 3.12). Carcasses from OPT and ZIL treatments were more likely ($P < 0.05$) to qualify for the USDA Yield Grade 1 and 2 categories and less likely ($P < 0.05$) to qualify for the USDA Yield Grade 3 category as compared with control. There were no differences in the distribution of USDA Yield Grade 4 and 5 carcasses among control, OPT, and ZIL treatments. Marbling score was similar for OPT and ZIL carcasses averaging Small^{11} and Small^{09}, respectively. Marbling score for the control carcasses was significantly higher ($P < 0.01$) than for BA treatment and averaged a Small^{32}. The likelihood

of an individual carcass within a pen of grading low Choice and above was reduced ($P < 0.01$) for the OPT (avg = 53.9%) and ZIL (avg = 49.7%) treatments as compared with controls (avg = 61.8%). Slaughter weight, ADG during the final 28 d, and ADG d 1 through slaughter was lower for the 12.5/3.5 treatments as compared with the 12.5/2.5 ($P < 0.05$) and 11.5/1.5 ($P < 0.10$) treatments. Crude protein withdrawal treatment had no effect on HCW and all other carcass variables evaluated. Lower slaughter weight by the 12.5/3.5 treatment and the effect of this reduced weight on ADG were likely a function of reduced gut fill due to a reduction in DMI by steers fed the 12.5/3.5 diets during the final 28 d on feed as compared with the 13.5/3.5 ($P < 0.05$), 12.5/2.5 ($P < 0.0.01$), and 11.5/1.5 ($P < 0.10$) treatments.

Nitrogen retention was 5.54, 5.43, 6.97, and 6.90% of N intake for the 13.5/3.5, 12.5/3.5, 12.5/2.5, and 11.5/1.5 CP treatments, respectively. Nitrogen excretion was 5,282; 4,654; 4,875; and 4,391 g/hd for the 13.5/3.5, 12.5/3.5, 12.5/2.5, and 11.5/1.5 CP treatments, respectively. Nitrogen excretion was greatest ($P < 0.001$) for the 13.5/3.5 CP treatment as compared with the remaining treatments. Differences between the 12.5/3.5 versus 12.5/2.5 ($P < 0.05$) and between the 12.5/2.5 versus 11.5/1.5 ($P < 0.0001$) treatments were also significant. Using the 12.5/2.5 or 11.5/1.5 CP treatment diets as compared with the 13.5/3.5 CP diet did not reduce feedlot performance, HCW, or USDA Quality and Yield Grade during the final 28 d. Considering the source and cost of non-protein nitrogen, significant savings could be obtained from using the 12.5/2.5 diet or the 11.5/1.5 diet as compared with using the 13.5/3.5 diet during the last 28d on feed.

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CHAPTER ONE

INTRODUCTION

Historically, there has been significant variation in weight, frame, flesh condition, and genetic make-up among individuals in each pen of feedyard cattle. Feedyard nutritionists have managed this situation by formulating diets with nutrient concentrations typically above those recommended by NRC (2000) for the average individual animal within the pen. This strategy provides most cattle with ample nutrients to meet their requirement for maintenance and gain. However, many cattle in the pen receive more nutrients than required. Excess nutrient intake reduces production efficiency and likely results in excess nutrient excretion into the environment.

Grouping cattle of similar weight into pens may reduce variation in nutrient requirements within each pen. This may allow specific diets with more precise nutrient concentrations to be formulated and provided to the cattle. Performance and/or production efficiency may improve and nutrient excretion into the environment may be reduced. Currently, the excretion of nitrogen and phosphorus are the primary environmental concerns. Cattle of varying initial weight may have varying requirements for rumen degradable intake protein (DIP) and rumen un-degradable intake protein (UIP). Providing the proper concentration and ratio of DIP to UIP may improve performance and/or production efficiency and may reduce nitrogen excretion into the environment.

In a review of opportunities to enhance performance and efficiency through nutrient synchrony, Cole and Todd (2008) suggested that crude protein (CP) concentration of dry-rolled corn-based diets could be decreased late in the feeding period with no adverse effects

on performance. The responses observed in steam-flaked corn based diets were less consistent. However, results observed in previous research at done by Wagner et at. 2010 suggest that feedlot performance by heavy yearling steers (≥ 390.09 kg individual weight) was affected by DIP concentration in the diet from d 0 through 83. From d 84 through slaughter, DIP concentration effects on performance were of lower importance. Reducing the amount of urea needed in the diet without adversely affecting performance could reduce cost of gain. Storage bins for finished feed and additional supplements at feedyards generally limit the number of diets and supplements that a feedyard can manage. Therefore, a logical time to remove DIP from the diet may be the last 20 to 42 days prior to slaughter when β – agonists (BA) are fed.

Beta-agonist feeding generally improves growth rate and as a result nitrogen retention. Improved nitrogen retention should result in reduced nitrogen excretion and in turn reduced nitrogen emissions into the environment. Preliminary data collected at the Southeast Colorado Research Center (SECRC) during the summer of 2008 demonstrated a 12.9% improvement in ADG by steers receiving Optaflexx (OPT) and an 8% reduction in ammonia emissions from the pen surface of these cattle (Marcillac, 2007).

Optaflexx[1] and Zilmax[2] (ZIL) are the two BA products currently available for use in feedlot diets. Currently, there are only two published studies directly comparing performance and carcass characteristics of Optaflexx and Zilmax; Averdano-Reyes et al. 2006, and Scramlin et al. 2010. In addition, the effect of DIP withdrawal on the effectiveness of BA feeding is not known.

[1] Ractopamine hydrochloride, Elanco Animal Health, Greenfield, IN
[2] Zilpaterol hydrochloride, Intervet/Schering Plough Animal Health, DeSoto, KS

Furthermore, the current global demand for meat animal protein combined with current contraction of the U.S. beef cow herd inventory require that feedyard producers continually reduce input costs and increase their efficiency to maintain supply of beef products. Consequently, efficiency of production continues to remain a strong driver in management of U.S. feedyards. Understanding the possible changes that new, efficiency improving products have in beef production will be essential to the continued sustainability of the cattle feeding industry.

The objectives of this research were: 1) to investigate the effect of reducing dietary DIP concentration on feedyard performance and carcass merit in heavy yearling steers; 2) to investigate the effect of reducing dietary DIP on the effectiveness of BA feeding; and 3) compare OPT and ZIL for yearling steers.

CHAPTER II

REVIEW OF LITERATURE

Degradable Intake Protein and Undegradable Intake Protein in Feedlot Diets

Degradable intake protein (DIP) is defined as protein that is degraded in the rumen of cattle and utilized by rumen microbes for the production of microbial protein. Undegradable intake protein (UIP), or bypass protein, is the protein that is not utilized by rumen microbes and passes into the small intestines to be broken down by enzymes and absorbed into the bloodstream, or by-passed in digestion all together and excreted in fecal material.

Previous research has shown that having an adequate blend of DIP and UIP in feedlot diets maximizes performance of feedlot cattle (Stock et al., 1981 and Sindt et al., 1993). Additionally, higher concentrations of UIP in dry-rolled corn diets have shown increases in ADG when compared to diets strictly relying on DIP with urea as the main supplemental CP source. However, more recent research (Gleghorn et al., 2004) has shown that DIP levels at 13% CP from 100% urea supplemental CP shown no differences in ADG, DMI, or G:F. This lack of differences could be attributed to corn processing methods or age, source and type, and initial body weight of the cattle on trial. Pretrial management could also play a factor in the contradictions noted above as well as digestibility of feedstuffs used. Moreover, as Cooper et al. (2002) demonstrated, steam flaking corn requires a higher concentration of DIP due the higher level of starch digestion taking place in the within the rumen.

In contradiction to the previously stated findings, Milton et al. (1997) found that N supplementation of 100% urea in dry-rolled corn in finishing diets did not maximize performance of finishing steers. Supplementing with true protein from SBM or cottonseed

meal provided degradable protein that increased microbial protein production and overall metabolizable protein supply.

Wagner et al. (2010) stated that NPN may be a an appropriate measure of dietary DIP and DIP requirements for steam-flaked corn diets are likely between 7.4 and 8.4 % of dietary DM. Wagner at al. (2010) placed NPN requirements at 2.55 to 3.55% of dietary NPN but saw that increasing UIP about 5.1% of DM did not improve performance or carcass merit. These results show that the relationship between DIP and UIP is still highly uncertain and dependent upon the grain source of the diet. Steam-flaked corn diets vs. dry-rolled corn diets offer different amounts of energy for microbial protein. Protein supplementation source (urea, SBM or cottonseed meal) also has shown different results on performance and carcass merit. These varied results support that more research needs to be done to explore the interaction between supplemental protein source, grain processing method, and UIP levels in feedlot diets.

Nitrogen Metabolism, Retention and Excretion in Feedlot Cattle

Metabolizable protein (MP) is defined as the true protein absorbed by the intestine, supplied by microbial protein and undegradable intake protein (NRC, 2000). Owens and Zinn (1988) divided protein requirements for ruminants into ammonia needs for rumen bacterial growth and amino acids for absorption in the small intestine. Additionally, they stress that microbial protein synthesis alone is not adequate enough to achieve higher rates of growth desired, but that it is dependent on the desired level of performance, environmental, ruminal, and feeding conditions. Dietary protein that escapes ruminal degradation by microbes supplements microbial protein production for ruminants. Ruminal escape of

dietary protein is difficult to measure and varies as well with feeding conditions. Supplying non-protein nitrogen, most often in the form of urea, can help improve ammonia levels in the rumen to achieve needed levels of amino acids. N sources that microbes utilize for protein synthesis originate from dietary protein, non-protein N, and N recycled to the rumen. NPN supplementation is generally only useful when if it provides needed ammonia for ruminal bacteria.

Diet manipulation to study protein status can be challenging because amino acids are both catabolized and synthesized in the rumen. However, bypass protein via coating methods, direct infusion through rumen cannula, or the use of digesta flow markers can provided valuable insight (Owens and Zinn, 1988). Maximizing N utilization by finding the correct balance between degradable intake protein and undegradable intake protein is important. Matching correct levels of N to biological conditions and stages of growth can be challenging in order to not only achieve optimal efficiency and reduce un-needed energy expenditure, but also decrease levels of N excreted into the environment, which can have adverse affects.

Cole et al. (2006) demonstrated that decreasing dietary CP (11.5% vs. 13.0%) for the entire feeding period would reduce apparent nitrogen excretion and volatilization, while not hurting feedlot performance. Huntington et al. (2001) showed that utilizing higher levels of ruminal escape supplemental protein reduced endogenous production of urea seeing lower concentrations of urea in blood and lower urinary urea N. With the addition of implants and increasing supplemental protein Huntington increased ADG and plasma urea N while lowering urinary urea N.

While knowledge of the relationship between UIP and DIP in an effort to more effectively utilize protein sources in feedlot diets is becoming more available, efforts must continue to be made to match proper protein supplement levels with production levels. Advances in efficiency and cost of production are of value, but reducing or minimizing environmental impact from excess N excretion will become increasingly important as competition for land resources and environmental regulations pressure the feedlot industry.

Effects of Varying Crude Protein Levels on Feedlot Performance and Carcass Characteristics

As Nitrogen commonly constitutes the most expensive element in feedlot cattle diets, methods of reducing cost or finding alternative sources of animal and plant protein feed ingredients are often explored. Additionally, as feedlot diets are formulated to meet the needs of an entire pen of cattle, often NRC requirements for NE_m and NE_g are over estimated to insure and meet the needs of the biological variances that exist in a group of cattle. This includes CP levels. By specifically targeting CP needs at various stages of growth and development of feedlot cattle, reduced cost could be achieved as well as unnecessary waste of nutrients. A further benefit of targeted nutrient use would be the reduction of excreted elements such as Potassium (K), Phosphorus (P), and Nitrogen (N) that can cause pollution issues in ground water. By reducing the amount of CP in feedlot diets during the last stages of the finishing period, when the energy demand for growth of the animal has minimized, it may be possible to reduce costs, and decrease potentially harmful elements being excreted. Gleghorn et al. (2004) examined the effects of CP concentration and CP source in feedlot cattle and found that a 13% CP diet when compared to a 11.5% and 14.5% CP diet

maximized ADG and found more pronounced differences in ADG during the initial days of the feeding period. For the first 28 days, ADG increased linearly with increased CP concentration. However, by the end of the trial, day 84 and day 112, response to CP concentration became quadratic, with the 13% CP concentration treatment group achieving the highest ADG. No differences in DMI were noted between the different CP concentrations during the overall feeding period, but gain to feed ratios followed similar results see in ADG with later feeding periods experiencing the best G:F ratio with the 13% CP concentration. Similar results were noted for HCW and DP. These results show that feeding cattle a steam-flaked corn based diet at a CP concentration of 13% with supplemental CP from urea provided the optimal performance.

Dartt et al. (1978), using soybean meal (SBM) as a supplemental protein source in a corn silage based finish diet, found that reducing crude protein for the final 84 days on feed reduced average daily gain. Steers that continued to receive supplemental SBM had an average daily gain of 0.87 kg whereas steers not receiving supplemental SBM only gained 0.61 kg per day. Efficiency of gain (measured in TDN/kg gain) was also affected with steers continuing to receive SBM performing better at 5.83 TDN/kg gain vs. 6.14 TDN/kg gain. Crude protein levels for this trial were at 11% before removal of SBM and during the second period were 10.6% for cattle that still had SBM in their diet and 7.3% for cattle that had SBM removed. These levels were calculated on a dry matter basis. There were no differences in carcass quality or grade between treatment groups in the trial. These results contradict previous results found in literature (Young et al., 1973, and Preston and Cahill, 1972, 1973, 1974); however, Dratt concluded that type and age of cattle, degree of finish, mature size, as well as time of supplement withdrawal contribute to these differences.

Thompson and Riley (1980) found that steers that had supplemental protein withdrawn from their diet after 84 days on feed showed no difference in performance when compared to steers fed the same level of supplemental protein the entire feeding period. Similar results are confirmed by Preston and Cahill, (1972, 1973); Putnam et al. (1969); and Riley and Harrison (1975). There were significant differences between treatment groups that received a 9% CP diet and the remaining groups that received a higher CP content (11%, 12-10.5%, 13-11-9%, and 15% CP) suggesting that feedlot performance suffers when diets contain less than 10.5% CP during the initial phases of the finishing period. This argument is supported by Braman et al. (1972), Kliewer et al. (1969), and Peterson et al. (1973), and is dependent upon weight of the animal being fed. Furthermore, Thomas et al. (1975) supports that withdrawal of supplemental protein early in the feeding period has the most detrimental effect on performance. However, after 84 days on feed, there was no effect of supplemental protein withdrawal on performance. Thomas continues to show that removal of supplemental protein in cattle with weights of 334 and 397 kg showed depression in feedlot performance, whereas cattle with or without supplemental protein in the ration at a weight of 409 kg during the last 60 days of the feeding period showed no difference in performance.

Cole et al. (2006) found that phasing feeding of crude protein (reducing CP levels during the final stages of the feeding period) adversely affected feedlot performance. However, when CP levels were kept consistent throughout the feeding period, performance remained similar between treatments receiving diets with 11.5% CP and diets with 13% CP. This suggested that at 11.5% CP adequate amounts of metabolizable protein and degradable intake protein were being provided.

These studies generally support the concept that once cattle have reached an acceptable weight, crude protein levels in the diet can be reduced to help achieve cost savings, while not sacrificing performance. While this could provided numerous benefits to cattle feeding, it is impossible for feedyards to individual weigh cattle on a regular basis and continually modify rations during the feeding process. Feedlots will continue to feed pens of cattle. The use of additional supplements and varying levels of quality in feedstuffs also provides challenging implementation of a feed program that would utilize crude protein withdrawal.

With the addition of beta agonists in a feedlot diet the question of adequate protein levels arises as beta agonists cause increased lean growth and decrease in adipose tissue deposition. A study done by Walker et al. (2006) examining the effects of protein source and level in feedlot heifers receiving ractopamine found that there was no need to increase metabolizable protein levels based on a steam-flaked corn diet with urea as the primary nitrogen supplement. They concluded that adequate DIP in a feedlot diet by urea was sufficient to provide metabolizable protein needs.

β-adrenergic agonists

β-adrenergic agonists (BAR) have been researched since the early 1980's in an effort to better understand their mechanisms of action and practical applications in both human and animal science. Human applications of BAR's have included inhalers to alleviate symptoms of asthma and beta blockers that assist in heart conditions. Animal science research has consistently shown increases in ADG, feed efficiency, and HCW with decreases in adipose tissue deposition (Watkins et al., 1990 and Armstrong et al., 2004). Most early research has

been conducted on rats and swine, with the swine industry adopting the earliest forms of commercially available BAR products available in the market place.

A study conducted by Ricke et al. (1999), examining the effects of Ractopamine hydrochloride on rats showed increased intake for the first 6 days of the 12 day trial. Increased body weight during the entire 12 days was observed when compared to controls, but no differences in feed efficiency were noted. Carcass CP% was increased for rats being fed Ractopamine hydrochloride, 70% vs. 66% for controls. Interestingly, apparent CP absorption, and CP retention were increased by RAC treatment but urinary and fecal CP excretion were not affected.

Mersmann published an article in 1998 in the Journal of Animal Science entitled, *Overview of the Effects of β-adrenergic Receptor Agonists on Animal Growth Including Mechanisms of Action.* What follows will be a summary of this article.

> β-adrenergic agonists bind to β-adrenergic receptors to produce a physiological response that causes a change in growth increasing accretion of skeletal muscle and reducing diposition of fat. This is accomplished with synthetic β-agonists being consumed orally. Physiological β-agonists include norepinephrine and epinephrine. β-agonist receptors fall into three sub-types: β_1-agonist receptors, β_2-agonist receptors, and β_3-agonist receptors. These sub-types are present on most mammalian cells with varying distribution by tissue in a given species and also a varying distribution within a given tissue between species. With the amino acid sequence varying for a given β-agonists receptor subtype across species and the distribution being varied on tissues, the effects of oral administration of β-agonists can be difficult and complex.

The mode of action for β-adrenergic receptor agonists is the activation of the G_s protein. This causes the α-subunit of the G_s protein to activate adenylyl cyclase. Adenylyl cyclase produces cyclic adenosine monophosphate (cAMP), a major intracellular signaling molecule. Cyclic AMP binds with protein kinase A to release the catalytic subunit that then phosphorylates numerous intercellular proteins. This phosporylation changes the transcriptional activity allowing for the mediated transcription of several genes in the mammalian cell and inactivation of some enzymes. Naturally occurring β-adrenergic receptor agonists include norepinephrine and epinephrine. Norepinephrine is the catecholamine sympathetic nervous system neurotransmitter molecule and epinephrine is produced in the adrenal medulla and is released to the plasma.

Interest in β-adrenergic receptors in the biomedical community has led to the development of thousands of organic molecules that bind to β-adrenergic receptors to act as both agonists and antagonists. Many of these applications are related to bronchial-tracheal musculature for asthma relief, and cardiovascular applications affecting heart rate and blood pressure.

Cunningham (1965) showed data of changing mammalian growth by the addition of agents that may indirectly or directly affect cAMP intracellular concentrations. Some of these agents included caffeine, theophylline, nicotine, and epinephrine. Clenbuterol, a β-adrenergic receptor agonist, was used in the early 1980's by American Cyanamid Co. to modify growth in animals showing increases muscle mass and decreased fat mass in sheep, cattle, pigs, and chickens when fed clenbuterol orally. Instances of increased weight gain and increased gain-to-feed

were also observed. Other β-adrenergic receptor agonists such as cimaterol, ractopamine, L 664,969, and salbutamol were studied finding similar results found with clenbuterol.

β-adrenergic receptor agonists have varying levels of effect depending on species. Chickens do not show as great a response to administration of β-adrenergic receptor agonists as seen in sheep. Hogs show an intermediate response and cattle are similar to sheep in the effectiveness of β-adrenergic receptor agonists. One reason for this is that some species have been more intensely selecting for growth rate and would not stand to gain as much from the β-AR agonist already being at a maximum biological growth rate. Other species have not undergone such intensive selection for growth rate, and thus have more potential to increase their growth rate. Differences between species may also exist due to a species difference in tissue composition and affinity for β-AR agonists. Additionally, the coupling of β-adrenergic receptor-complex to the signal transduction system, and delivery of the β-AR agonist compound to the receptor site may differ between species.

β-AR exist on almost every mammalian cell embedded in the plasma membrane. Receptors are made up of amino acids with seven relatively hydrophobic transmembrane domains anchoring the receptor to the plasma membrane. The ligand bidding site is located at the center of the seven transmembrane domains, involving amino acids from several of the domains. To prevent indefinite activation of the β-AR, the agonists must be either degraded, removed by reuptake mechanisms, or the receptor itself inactivated. It is possible that the β-AR could be removed from the

plasma membrane due to chronic stimulation, resulting in a reduction of the effectiveness of an agonist or antagonist present.

β-AR are classified into sub-types to better describe their complex adrenergic function. Some tissues posses only a specific sub-type of β-AR allowing for more directed responses by a tissue exposed to its corresponding β-AR agonists. β-AR agonists subtypes are classified as B_1-AR, β_2-AR, and β_3-AR.

Specific research has shown that the pharmacology of β_3-AR is distinctly different from the other two sub-types. Its structure in the fourth intercellular loop provides few sites for inactivation by phosphorylation. Additionally, several antagonists for B_1-AR and β_2-AR are either partial or full agonists for β_3-AR. This leads to some species having varied responses when exposed to β-AR of all three sub-types.

Molecular biology studies have shown that β-AR can be categorized by different sized RNA transcripts, protein sizes and amino acid sequences. Amino acid sequencing of β-AR shows a 50% homology in amino acid sequence among β-AR sub-type within a single species, and a 75% homology among a specific sub-type across species.

Modulation of β-AR sub-types has shown desensitization to occur less in β_3-AR, where β_2-AR is more readily desensitized than β_1-AR.

When studying effects of β-AR on skeletal muscle and adipocyte tissues in cattle using binding analysis, there tends to be more β_2-AR. One study by Sillence and Matthews, 1994, showed predominantly β_2-AR present where another by Van Liefde et al., 1994 showed approximately 75% β_2-AR and 25% β_1-AR. There is currently no

evidence of β_3-AR being present on the adipocyte tissues of bovine species using biding analysis. However, β_3-AR have been transcribed in bovine tissue samples, most likely from few scattered brown adipocytes in white adipose tissue remaining in the adult after the neonatal period. B_3-AR is the predominant sub-type found in brown adipose tissue of the bovine fetus.

Orally administered β-AR agonists in sheep, cattle and swine show an increase in muscle mass. Postnatal growth of skeletal muscle is the result of hypertrophy leading to an increase protein muscle synthesis or a decrease in protein muscle degradation or both as the cause of this increase in muscle mass. Evidence from previous experiments has shown this to be true, but contradicting experiments have also been reported. This could be due to the fact that muscle protein synthesis and degradation are difficult to measure and changes that occur are small. These contradictions may be the result of the status of the endocrine system in the animal being observed, as β-AR agonists may depend on the glucocorticoid status of the animal. When mammals are treated with β-AR agonists, the amount of RNA transcripts for several skeletal muscle proteins increases. An expected response to β-AR agonists should correlate with the number of β-AR on a specific tissue type, however β-AR tend to move on and off the membrane, become inactivated by phosphorylation, and the measured response is usually only based on the activation of only a few receptors, leaving many spare receptors on the tissue.

A decrease in carcass mass fat is another effect of oral β-AR agonists. This is resulted from stimulated adipocyte triacylglycerol degradation and inhibited fatty acid and triacylglycerol synthesis. In some in vitro cases chronic exposure of some

agonists causes increased lipolytic or decreased lipogenic rates. Carcass fat seems to have a more variable response to β-AR agonists as compared to the measured affects on skeletal muscle. This difference in response could be due to genetic differences in animal species being tested or subtle differences in experimental design.

Furthermore, as β-AR agonists are continually fed, β-AR cells tend to desensitize with adipose tissue β-AR's decreasing at a greater extent than skeletal muscle β-AR. As β-AR cells are present on the surface of multiple different cell and tissue types throughout the mammalian body, the effects of the exposure to these various cells by β-AR agonists fed to an animal could contribute to its mechanism of action. This could include increased blood flow to certain regions of the body bringing more substrates and energy to skeletal muscle for protein synthesis and carry away nonsterified fatty acid from adipose tissue contributing to lipid degradation. Blood flow is most likely increased to organs as well due to increased heart rates found in animals administered β-AR agonists. Additionally, acute increased levels of plasma insulin have been found in cattle receiving β-AR agonists while plasma epinephrine and norepinephrine concentrations remained unchanged. Finally, β-AR controlled metabolic pathways could be altered from β-AR agonists administration resulting in changes in plasma concentrate levels of glucose or lactate. All of these effects, whether acting together or singly, contribute to the prescribed affect of feeding β-AR agonists in a specific diet targeting specific tissues.

In summary, β-AR agonists can cause increased muscle mass and decreased adipose tissue deposition when fed to cattle. Due to the presence of β-AR on all mammalian cells, the mechanisms of action are complex with several direct and indirect actions leading to the

prescribed effect. Increased blood flow, modifications in metabolic rates, secondary effects on other hormones can also occur, but direct exposure of β-AR agonist to β-AR cells on skeletal muscle and adipose tissue is probably the main action of response. β-AR cell distribution and presence as well as β-AR subtype variation across species and between species lead to variable responses in β-AR agonist treatment of a specific species.

FDA Approval of Beta-agonists as Medicated Feed for Cattle

The United States Food and Drug Administration approved ractopamine-HCl under the trade name Optaflexx^{TM} 45 in June 2003, manufactured by Elanco Animal Health, A Division of Eli Lilly & Co. It is approved for use in cattle being fed in confinement for slaughter by oral administration. Two dosage levels have been approved: one at a level of 8.2 to 24.6 grams per ton, and one at 9.8 to 24.6 grams per ton. These dosage rates are approved for increased rate of weight gain, improved feed efficiency, and increased carcass leanness in cattle fed in confinement for slaughter during the last 28 to 42 days on feed. Ractopamine-HCl has been approved in the form of Type A medicated article, Type B liquid medicated feed, and Type B medicated feed (U.S. Food and Drug Administration, www.accessdata.fda.gov/scripts/animaldrugsatfda/details.cfm?dn=141-221).

The United States Food and Drug Administration approved Zilpaterol-HCl under the trade name Zilmax® in August 2006, manufactured by Intervet/Schering-Plough, Inc. It was approved for use in cattle being fed in confinement for slaughter by oral administration. Zilpaterol-hydrochloride has been approved at a rate of 6.8 grams per ton of feed to provide 60 to 90 milligrams zilpaterol-hydrochloride per head per day. Indications for using the Type A medicated article include increased rate of weight gain, improved feed efficiency and

increased carcass leanness in cattle fed in confinement for slaughter during the last 20 to 40 days on feed. It must be feed continuously as the sole ration during the last 20 to 40 days on feed. Zilpaterol-hydrochloride has a withdrawal time of 3 days when fed to cattle (U.S. Food and Drug Administration, www.accessdata.fda.gov/scripts/animaldrugsatfda/details.cfm?dn=141-258 and http://www.intervetusa.com/news/2008-05-07_zilmax_post-approval_research_nears_completion.aspx).

Effects of Ractopamine-HCl on Feedlot Performance and Carcass Merit

Numerous studies have been performed to evaluate the effects of ractopamine-HCl on feedlot performance and carcass merit in feedlot cattle. The results show increases in red meat yield and decreases in carcass fat deposition. Understanding the proper timing of being added to that diet and the duration that ractopamine-HCl should be included have been of the most interest by researchers. Additionally, method of inclusion in the finishing diet (top dress vs. total mix ration) and protein source has been explored.

Schroeder et al. (2003a) and Laudert et al. (2004) found a 16% improvement in feed efficiency when feedlot steers were fed 20ppm ractopamine for 28 or 42 days.
Gruber et al. 2007, found that including RAC during that last 28 days on feed at 200 mg/hd/day improved (P = 0.001) ADG and G:F but did not affect DMI (*P* = 0.48). Interestingly, dressing percentage, adjusted back fat, or KPH% were not affect by RAC supplementation. However, steers receiving RAC did have 7 kg heavier carcasses and 2.8% larger LM area. There were no differences noted in the mean YG score between RAC and

control groups, but there was a shift in YG distribution with RAC supplemented steers having a higher percentage of YG 2 and a tendency fewer YG 3 carcasses vs. controls. Walker et al. (2006) found similar results in feedlot heifers fed ractopamine at 200 $mg \cdot hd^{-1} \cdot d^{-1}$ with increases in ADG and efficiency of gain by 18% and 17%, respectively. Results showed an increase in final BW of 8.3 kg as well as an increase in HCW by 6.9 kg for heifers fed ractopamine. However, carcass data showed similar results found in previous studies where dressing percentage, LM area, 12^{th} rib fat thickness and USDA YG and marbling score were not affected by ractopamine.

Winterholler et al. (2007) and Abrey et al. (2007) conducted trials with ractopamine HCl and found similar results of increases in ADG, G:F, and final BW, as well as heavier HCW, larger LM areas, and decrease in 12^{th} rib fat thickness. No effects on USDA YG or marbling score were noted.

Effects of Zilpaterol-hydrochloride on Feedlot Performance and Carcass Merit

Several studies have been conducted evaluating the effects of zilpaterol-hydrochloride on feedlot performance and carcass merit in feedlot steers. In a clinical study done by Montgomery et al. (2008), it was shown supplementing feedlot steers at 8.3 mg/kg of DM increased final body weight by 11.6 kg, increased ADG by 36%, and increased G:F by 28%. The inclusion of zilpaterol-HCl tended to decrease dry matter intake by 2% in the trial. Additionally, HCW was increased by 16.4 kg, dressing percentage was increased by 1.5-percentage units, and LM area was increased by 8.23 cm^2. Twelfth-rib fat and KPH were not affecting by feeding zilpaterol-hydrochloride, however, marbling score and quality grade

were both decreased. Calculated yield grade was improved and the percentage of USDAYield grade 1 carcasses was increased.

In a joint effort by Intervet/Schering-Plough, Inc., Oklahoma State University, Cactus Research Ltd., and West Texas A&M University, 3,757 feedlot steers were evaluated for the feeding effects of zilpaterol-HCl with or without monensin and tylosin. Zilpaterol-HCl was supplemented at 8.3 mg per kg of dry matter for 30 d at the end of the finishing period. Montgomery et al. (2009), showed results of increased ADG by 3.4% and increased G:F by 3.9%. Zilpaterol increased dressing percentage by 1.2 percentage units as well as HCW by 13 kg. LM area was increased by an average of 8.0 cm^2 to zilpaterol inclusion in the diet. Additionally, treatments with zilpaterol showed a decrease in marbling score regardless of monensin or tylosin inclusion or withdrawal. Calculated yield grades were improved by feeding zilpaterol as well. Twelth-rib fat thickness was decreased by 8.4% for zilpaterol treatments and decreased marbling score.

Vasconcelos et al. (2006) that showed an increase in ADG for the final days on feed during zilpaterol treatment and for the entire experimental period. Results showed a decrease in DMI which, when considering the increase in ADG, allowed for an increase in G:F during treatment period. Carcass trait response showed an increase in HCW for all treatments receiving zilpaterol well as an increase in dressing percent, a decrease in 12^{th}-rib fat deposition, an increase in LM area, and a decrease in yield grade when compared to cattle not receiving zilpaterol. Additionally, cattle fed zilpaterol showed a decrease in marbling score as compare to control treatments. In this trial, zilpaterol at 8.3 mg per kg of dry matter.

These trials show that zilpaterol used as a feed additive in the finishing period of feedlot cattle consistently provides improvement in feedlot performance and HCW.

Previous Comparisons of Ractopamine Hydrochloride and Zilpaterol Hydrochloride in Feedlot Performance and Carcass Characteristics

Ractopamine hydrochloride and Zilpaterol hydrochloride are the only two beta agonist feed additive products commercially available at this time. Comparative research between these two products is limited, but provides valuable insight to proper application and utilization of these products when finishing feedlot cattle to slaughter. It is important to note that ractopamine-HCl is a type 1 beta agonist, while zilpaterol-HCl is a type 2 beta agonist. Skeletal muscular tissue tends to have a higher percentage of type 2 beta agonist receptors on their cell membrane surface, providing possible differences in efficacy and effectiveness of the two products.

A study conduct by Avedano-Reyes et al. (2006) compared ractopamine-HCl and zilpaterol-HCl when fed to feedlot steers for the final 33 days on feed. Three treatment categories were administered: Ractopamine-hydrochloride at 300 mg per head per day, Zilpaterol-hydrochloride at 60 mg per head per day, or no beta-agonist for the final 33 days of the finishing period. Results showed increased ADG of 26% from zilpaterol-HCl and 24% from ractopamine-HCl. Steers receiving the ractopamine-HCl treatment consumed less dry matter when compared to controls and steers receiving the zilpaterol-HCl treatment showed no difference in dry matter consumed compared to controls. Gain-to-feed ratio was significantly improved when comparing beta-agonist treatments to controls.

Zilpaterol-HCl increased HCW by 7% ($P < 0.001$) and ractopamine-HCl showed a 5% increase in HCW when compared to controls. Additionally, LM area was increased for steers receiving zilpaterol-HCl when compared to controls, but no difference was found

between steers receiving ractopamine-HCl and control steers. Zilpaterol-HCl treatments showed a trend toward less 12^{th} rib fat than control treatments. No differences in 12^{th} rib fat between ractopamine-HCl and control steers were found.

Diets in this experiment were formatted to offer 13.5% crude protein across all diets, treatments and controls with the base ingredient being steam-rolled wheat grain. The results of Avedano-Reyes et al. (2006) are consistent with most high plains feedlot diets in the United States feeding a steam flake corn based diet and shows that utilizing beta-agonists to enhance feedlot performance and carcass merit offers their intended results.

Scramlin et al. (2010) conducted a similar studying between ractopamine-HCl and zilpaterol-HCl. Beta agonist treatments were applied for the final 33 days of the finishing period, with zilpaterol treatments being withdrawn the final three days. Ractopamine was included in the ration at 200 $mg \cdot hd^{-1} \cdot d^{-1}$ and zilpaterol was fed at an inclusion rate of 75 $mg \cdot hd^{-1} \cdot d^{-1}$. Results showed that both ractopamine and zilpaterol increased final body weight, ADG, feed-to-gain ratio, and HCW when compared to control groups. Zilpaterol compared to RAC, decreased ADG, average daily feed intake, and final body weight; however, HCW and dressing percentage were increased by zilpaterol. There was no effect on carcass merit from RAC, but zilpaterol treated steers showed decreased 12^{th} rib back fat and KPH, increased LM area, and decreased yield grade when compared to controls. There was no difference between treatments on carcass quality.

The findings of these 2 studies show that the use of ractopamine or zilpaterol during the final finishing period improves feedlot efficiency and carcass merit when used at the appropriate dosage levels. Additionally, the results show that in comparison, ractopamine and zilpaterol do not vary greatly in their effect on carcass quality, with greater differences in

carcass yield. Given the various number of marketing opportunities cattle feeders have today, utilization of BA's during the finishing period could provide great opportunity for capturing additional value.

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CHAPTER THREE

EXPERIMENT

THE EFFECT OF CRUDE PROTEIN WITHDRAWAL AND THE USE OF β – AGONISTS ON FEEDLOT PERFORMANCE, CARCASS MERIT, AND THEORETICAL NITROGEN RETENTION AND EXCRETION FOR HEAVY YEARLING STEERS

R. K. Peterson[1], J. J. Wagner[1], T. E. Engle[1], and T. C. Bryant[2]

[1]Colorado State University, Department of Animal Sciences, Fort Collins, CO 80523-1171

[2]JBS Five Rivers Cattle Feeders, LLC, Greeley, CO 80634

ABSTRACT

THE EFFECT OF CRUDE PROTEIN WITHDRAWAL AND THE USE OF β – AGONISTS ON FEEDLOT PERFORMANCE, CARCASS MERIT, AND THEORETICAL NITROGEN RETENTION AND EXCRETION FOR HEAVY YEARLING STEERS

Crossbred steers (n=864; BW = 347.3 kg +/- 7.67 SEM) were used in a 3 x 4 factorial experiment to study the effects of β – agonist (BA) administration and crude protein (CP) withdrawal during the last 28 d on feed. Three BA treatments were evaluated: no BA, 200 mg/hd/d from Optaflexx (OPT) for 28 d, and 75 mg/hd/d from Zilmax (ZIL) for 20 d. The 4 CP withdrawal treatments included: 1) 13.5% CP, 3.5% crude protein equivalent (CPE) from non-protein nitrogen (NPN) from d 0 through slaughter (13.5/3.5); 2) 13.5/3.5 until 28 d remained on feed followed by 12.5% CP, 3.5% NPN (12.5/3.5); 3) 13.5/3.5 until 28 d remained on feed followed by 12.5% CP, 2.5% NPN (12.5/2.5); and 4) 13.5/3.5 until 28 d remained on feed followed by 11.5% CP, 1.5% NPN (11.5/1.5). There were no interactions ($P > 0.32$) between BA and CP withdrawal treatment; therefore, only main effects are discussed. Average slaughter weights and ADG were greater ($P < 0.01$) for steers fed BA as compared with controls. More than a 35% improvement ($P < 0.001$) in G:F for the final 28 d was observed for steers fed BA as compared with controls. Least squares means for HCW, adjusted for live weight at treatment initiation, was 9.21 kg heavier ($P < 0.01$) for ZIL steers as compared with controls and 5.81 kg heavier ($P < 0.05$) for ZIL as compared with OPT. Dressing percentage was increased for steers fed ZIL versus controls (64.4 versus 63.4%, $P < 0.001$) and OPT ($P < 0.01$). Longissimus muscle area for control carcasses (avg = 32.87

cm^2) was lower ($P < 0.06$) than OPT (avg = 33.53 cm^2) which was lower ($P < 0.01$) than ZIL (avg = 34.59 cm^2). Yield grades were similar for OPT and ZIL (3.01 versus 2.97), and were reduced ($P < 0.05$) as compared with controls (avg = 3.12). Carcasses from BA treatments were more likely ($P < 0.05$) to qualify for the USDA Yield Grade 1 and 2 categories and less likely ($P < 0.05$) to qualify for the USDA Yield Grade 3 category as compared with controls. Marbling score was similar for OPT and ZIL carcasses averaging $Small^{11}$ and $Small^{09}$, respectively, with control carcass averaging $Small^{32}$. Nitrogen excretion was 5,282; 4,654; 4,875; and 4,391 g/hd for the 13.5/3.5, 12.5/3.5, 12.5/2.5, and 11.5/1.5 CP treatments, respectively. N excretion was greatest ($P < 0.001$) for the 13.5/3.5 CP treatment. Differences between the 12.5/3.5 versus 12.5/2.5 ($P < 0.05$) and between the 12.5/2.5 versus 11.5/1.5 ($P < 0.0001$) treatments were also significant. Using the 12.5/2.5 or 11.5/1.5 CP treatment diets as compared with the 13.5/3.5 CP diet did not reduce feedlot performance, HCW, or USDA Quality and Yield Grade during the final 28 d. Considering the source and cost of NPN, significant savings could be obtained from using the 12.5/2.5 diet or the 11.5/1.5 diet as compared with using the 13.5/3.5 diet during the last 28d on feed.

INTRODUCTION

Variation in weight, frame, flesh condition, and genetic make-up among individuals in each pen of feedyard cattle is fairly common throughout the industry. Feedyard nutritionists have managed this situation by formulating diets with nutrient concentrations typically above those recommended by NRC (2000) for the average individual animal within the pen. This approach provides most cattle with sufficient nutrients to meet their requirement for maintenance and gain. However, many cattle in the pen receive more nutrients than required. Excess nutrient intake reduces production efficiency and likely results in excess nutrient excretion into the environment.

Currently, the excretion of nitrogen and phosphorus are primary environmental concerns. Cattle of varying initial weight may have varying requirements for rumen degradable intake protein (DIP) and rumen un-degradable intake protein (UIP). Providing the proper concentration and ratio of DIP to UIP may improve performance and/or production efficiency and may reduce nitrogen excretion into the environment.

Cole and Todd (2008) suggested that crude protein (CP) concentration of dry-rolled corn-based diets could be decreased late in the feeding period with no adverse effects on performance. The responses observed in steam-flaked corn based diets have been less consistent. However, results observed in previous research at done by Wagner et at. (2010) suggest that feedlot performance by heavy yearling steers (≥ 390.09 kg individual weight) was affected by DIP concentration in the diet from d 0 through 83. From d 84 through slaughter, DIP concentration effects on performance were of lower importance.

Reducing the amount of urea needed in the diet without adversely affecting performance could reduce cost of gain. Storage bins for finished feed and additional supplements at feedyards generally limit the number of diets and supplements that a feedyard can manage. Therefore, a logical time to remove DIP from the diet may be the last 20 to 42 days prior to slaughter when β – agonists (BA) are fed.

Beta-agonist feeding generally improves growth rate and as a result nitrogen retention. Improved nitrogen retention should result in reduced nitrogen excretion and in turn reduced nitrogen emissions into the environment. Preliminary data collected at the Southeast Colorado Research Center (SECRC) during the summer of 2008 demonstrated a 12.9% improvement in ADG by steers receiving Optaflexx (OPT) and an 8% reduction in ammonia emissions from the pen surface of these cattle (Marcillac, 2007).

Optaflexx[3] and Zilmax[4] (ZIL) are the two BA products currently available for use in feedlot diets. Currently, there are only two published studies directly comparing performance and carcass characteristics of Optaflexx and Zilmax; Averdano-Reyes et al. 2006, and Scramlin et al. 2010. In addition, the effect of DIP withdrawal on the effectiveness of BA feeding is not known.

The objectives of this research were: 1) to investigate the effect of reducing dietary DIP concentration on feedyard performance and carcass merit in heavy yearling steers; 2) to investigate the effect of reducing dietary DIP on the effectiveness of BA feeding; and 3) compare OPT and ZIL for yearling steers.

[3] Ractopamine hydrochloride, Elanco Animal Health, Greenfield, IN
[4] Zilpaterol hydrochloride, Intervet/Schering Plough Animal Health, DeSoto, KS

MATERIALS AND METHODS

Cattle Source and Processing

Eight hundred sixty four crossbred yearling steers were selected from a group of 1,091 steers. Steers arrived at Colorado Beef Feeders (CBF), JBS Five Rivers Cattle Feeding, L.L.C., from September 26 through October 12, 2008 (Table 3.1). Upon arrival at CBF, steers had overnight *ad libitum* access to long-stemmed grass hay and water. During the morning following arrival, steers were trailed to the Southeast Colorado Research Center (SECRC) for processing. The study started in 2 blocks: the first on October 10, 2008 and the second on October 17, 2008.

Processing procedures included the application of lot tags and individual electronic identification tags, vaccination with Presponse S-Q (Fort Dodge Animal Health, Overland Park, KS) and Pyramid II plus Type 2 BVD (Fort Dodge Animal Health, Overland Park, KS) respiratory vaccines injection with Promectin (Vedco, Inc., St. Joseph, MO), and drenching with Synanthic (Fort Dodge Animal Health, Overland Park, KS) to control internal parasites, and implanting with Revalor-S (Intervet Animal Health, DeSoto, KS).

Treatments

Twelve treatments arranged in a 3 x 4 factorial configuration were used in the study. Treatment factors evaluated included: β – agonist administration (control; ractopamine-HCl fed at 200 $mg \cdot hd^{-1} \cdot d^{-1}$, Elanco Animal Health, Greenfield, IN; or zilpaterol-HCl fed at 75 $mg \cdot hd^{-1} \cdot d^{-1}$; Intervet/ScheringPlough, DeSoto, KS) and four crude protein withdrawal treatments. Crude protein withdrawal treatments included: 1) 13.5% crude protein (CP), 3.5

% crude protein equivalent (CPE) from non-protein nitrogen (NPN) from d0 through slaughter (13.5/3.5); 2) 13.5/3.5 until the final 28 days on feed then 12.5% CP, 3.5% CPE from NPN through slaughter (12.5/3.5); 3) 13.5/3.5 until the final 28 days on feed and then 12.5% CP, 2.5% CPE from NPN through slaughter (12.5/2.5); and 4) 13.5/3.5 until the final 28 days on feed then 11.5% CP, 1.5% CPE from NPN through slaughter (11.5/1.5).

Randomization

Steers from each arrival block were weighed individually and assigned breed type scores on trial d -1. Steers were ranked by weight, and individuals that were beyond ± 2 SD from the mean were removed from the study. Steers showing excessive Brahman, Longhorn, of Dairy breed character were removed from further consideration for the study. Remaining steers in each block were assigned a random number using Microsoft Excel 2003. Sufficient steers with the lowest random numbers were removed from further consideration for the study leaving 432 eligible steers for each block. For each starting block, steers were ranked by weight within breed type and divided into 4 weight replicates. Within each block by breed type by weight replicate group, each successive group of 12 steers were assigned to pens 1 through 12 based on their successive random number with the lowest random number assigned to pen 1 and the highest random number assigned to pen 12. By following these procedures, each block consisted of 4 weight replicates, each containing 12 pens of 9 steers. Breed type distribution was similar for all pens.

On February 2, 2009, all steers were weighed and pens were reassigned to weight replicate based on pen weight. Pens were ranked by weight and stratified into weight

replicates 1 through 8 (twelve pens each) without regard to arrival block. Within each weight replicate, pens were assigned randomly to 1 of 12 treatment combinations.

Nutrition

A starter, step-one, and step-two diet (Table 3.2) were used to acclimate the steers to steam-flaked corn. Diets were formulated to meet or exceed the requirements for all vitamins and minerals listed by NRC (2000). All finishing diets (Table 3.3) contained 6% neutral detergent fiber solely accounted for from corn silage as the roughage source and 7.5% ether extract. Rumensin and Tylan were included in the finishing diet at 33 and 11 mg/kg DM, respectively. Vitamins, minerals, urea, and feed additives were added to all diets in the form of a meal supplement (Tables 3.4 and 3.5).

The control finishing diet was fed to all treatments until the last 28 days on feed and contained 13.5% CP and 3.5% CPE from NPN. As replicates appeared to be 28 days away from their desired finish weight and grade, the control diet continued to be fed to pens assigned to the 13.5/3.5 treatments and the appropriate diets with reduced DDG and/or urea was fed to the remaining pens. Treatment diets were formulated to contain equal concentrations of NDF from roughage, calcium, potassium, magnesium, and ether extract. Also, with 28 days remaining on feed, Optaflexx was included in the appropriate diets to provide 200 $mg \cdot hd^{-1} \cdot d^{-1}$. Zilmax was included in the appropriate diets with 24 days on feed remaining to facilitate a twenty day, 75 $mg \cdot hd^{-1} \cdot d^{-1}$ (7.56g/ton, DM basis) feeding program with the required 3 day withdrawal before slaughter.

Diets were fed twice daily and manufactured immediately prior to feeding. Feed bunks were evaluated each morning at 0700 hr and were managed to achieve *ad libitum*

intake. Generally, only a few crumbles of feed remained in each bunk at this time. If bunks were slick for 2 consecutive days, feed delivery was increased by 0.18 kg DM per head. Conversely, if bunks contained excessive feed, feed delivery was reduced an appropriate amount to achieve only a few crumbles of feed remaining in the bunk each morning. Samples of feed ingredients and rations were obtained weekly. Dry matter (DM) of feed ingredients and rations were determined weekly at SECRC by drying a portion of each sample in a convection oven at 60°C for 48 hours. Feed ingredients and ration samples were composited by month and sent to a commercial laboratory for routine nutrient analysis. Feed refusals were measured and samples obtained for DM analysis whenever feed became spoiled due to adverse weather or on weigh days. Feed refusals were dried at SECRC in a convection oven at 60°C for 48 hours.

Dry Matter Intake Determination

Dry matter consumption for each pen was calculated by subtracting the amount of DM weighed back from the amount of DM delivered and dividing the result by head days for the pen. Dry matter deliveries were calculated by multiplying the as-fed feed delivered to each pen by average DM concentration as determined by drying oven at SECRC for each diet during each period. Feed refusals were weighed and sampled for DM determination whenever feed became spoiled due to adverse weather conditions, on weigh days, and at the conclusion of the study. Feed refusal samples were evaluated for DM content at SECRC by drying samples for 48 hours in a 60°C forced air oven. The amount of DM weighed back was calculated by multiplying the feed refusal for each pen by the DM concentration as determined by drying oven at SECRC for each weigh-back.

Weighing Conditions

The initial weights used for the study were the average of 2 individual weights obtained on d -1 and d 0. Final weights are the average of 2 individual weights obtained on 2 successive days immediately prior to slaughter (March 10 and 11, 2009 for replicates 7 and 8, March 31 and April 1, 2009 for replicates 4, 5, and 6, April 14 and 15, 2009 for replicates 1, 2, and 3). Interim individual weights were obtained on December 23, 2008 and February 2, 2009. Pen weights were obtained at the start of treatment administration (February 12, 2009 for replicates 7 and 8; March 4, 2009 for replicates 4, 5, and 6; and March 19, 2009 for replicates 1, 2, and 3) and at approximately 1 week intervals during the final 28 days on feed. Growth curves for each β – agonist treatment constructed by plotting body weight versus days on treatment.

Net Energy Recovery

Net energy requirements for maintenance (NEm) and gain (NEg) for each pen of steers from d 0 through treatment initiation, from the initiation of each treatment through slaughter, and from d 0 through slaughter were calculated using equations published by NRC (2000). Net energy for maintenance and NEg derived from the diet for each pen were calculated from pen performance and pen requirements for NEm and NEg using the quadratic equation derivation of the energy equations (Appendix A; further described by Zinn, 1992).

Nitrogen Intake, Retention, and Excretion

Nitrogen intake but the average steer in each pen for the final 28 d on feed was calculated as (DMI x CP% / 6.25) x 28. Nitrogen retention by the average steer in each pen during the final 28 d on feed was calculated using initial and final pen empty body weight according to NRC (2000) equations. Nitrogen retained (g) = (Protein retained (kg) / 6.25) x 1000; where 6.25 is a function of the average protein containing 16% nitrogen. Protein retained (kg) = empty body protein at slaughter (EBPF), kg – empty body protein at treatment initiation (EBPI), kg. $EBPF = 0.235 \times EBW_{slaughter} - 0.00013 \times (EBW_{slaughter})^2 - 2.418$. $EBPI = 0.235 \times EBW_{initaial} - 0.00013 \times (EBW_{initial})^2 - 2.418$. EBW = 0.891 x SBW, where SBW equals shrunk body weight (kg). Shrunk Body Weight = Scale weight (kg) – 4% shrink. Nitrogen excretion by the average steer in each pen was assumed to equal nitrogen intake less nitrogen retention.

Cattle Observations

Pens were observed daily to monitor cattle for health problems. Steers showing significant signs of disease were removed from the pens and assigned scores of 0 or 1 for the following respiratory symptoms: eye discharge, nasal discharge, coughing, rapid breathing, and depressed appearance. Rectal body temperatures were also recorded for suspect steers that were removed from the pen. Two additional points were assigned to steers exhibiting body temperatures greater than 39.7°C. Steers with total of four or more points were considered morbid and treated according to the appropriate treatment schedule and immediately returned to the pen. If problems persisted concerning the health status of

specific steers, they were removed from the trial. Steers that died during the course of the trial were necropsied to determine the cause of death.

Carcass Data Collection

Steers were slaughtered in 3 groups. The first group was slaughtered (replicates 7 and 8) at the JBS Plant in Cactus, Texas on March 12, 2009. The second (replicates 4, 5, and 6) and third (replicates 1, 2, and 3) groups were slaughtered at the JBS Plant in Greeley, Colorado on April 2 and April 16, 2009, respectively. Carcass data were collected by Cattlemen's Carcass Data Collection Service for steers slaughtered in Texas and by Diamond T Livestock Services Inc. for steers slaughtered in Colorado. On the day of slaughter, steers were fed approximately 30% of their daily feed allowance at 0700 hr and trailed to CBF for shipment at approximately 1130 hr. Steers were transported to JBS and slaughtered at the beginning of "B" shift. Slaughter order, carcass tags, and HCW were recorded on the day of slaughter. Fat depth, LM area, kidney, pelvic and heart fat (KPH), marbling score, USDA quality grade, and USDA yield grade were recorded following a 36 hr chill. Liver abscess data were inadvertently not recorded at the Colorado slaughter location.

Data Analysis

Feedlot performance including nitrogen retention and continuous carcass data including HCW, dressing percentage, fat depth, LM area, KPH, marbling score, and calculated yield grade data were analyzed as a randomized block design using PROC MIXED of SAS (Statistical Analysis System, release 9.1, Cary, NC). Factors included in the models as fixed classification effects were β – agonist treatment, crude protein treatment, and

the interaction between β – agonist and crude protein. Replicate was included in the model as a random variable. Carcass categorical data, including HCW category, USDA quality grade, and USDA yield grade were analyzed using PROC GLIMMIX of SAS to calculate the likelihood that an individual carcass was classified into each HCW and quality and yield grade category. Pens were used as the experimental unit for all data analyzed.

Growth curve data were analyzed using mixed model procedures appropriate for a repeated measure design (Littell et al., 1998). Factors included in the models as fixed classification were β – agonist treatment, crude protein treatment, and the interaction between β – agonist and crude protein treatment. Linear and quadratic effects of the day of treatment (DAY) were included in the initial models and remained in the final models only when $P < 0.10$. Replicate was considered a random variable.

Pre-planned contrasts were used to β – agonist treatment differences when a significant F-test ($P < 0.10$) was observed. Contrasts of interest included: Control versus β – agonist and Optaflexx versus Zilmax. The PDIFF option of the LSMEANS statement of SAS was also used to compare Control versus Optaflexx and Control versus Zilmax. Treatment differences for the crude protein treatments were examined when a significant F-test ($P < 0.10$) was found. Crude protein treatment means were separated using the PDIFF option of the LSMEANS statement of SAS.

Finishing diet nutrient concentration data were analyzed using PROC MIXED of SAS. Two models were used for this analysis. The first model included diet (pre-treatment and all 12 treatment combination diets) in the model as a fixed effect and sample within diet was considered a random effect. For this analysis, the PDIFF option of the LSMEANS statement of SAS was used to compare the pre-treatment diet to each of the treatment diets.

The second model evaluated the treatment diet data as a 3 x 4 factorial arrangement for a completely randomized design. Fixed effects in the model included β – agonist, crude protein treatment, and the interaction between β – agonist and crude protein treatment. Means for the treatment diets were separated when significant F-tests ($P < 0.10$) were observed for each treatment factor. Contrasts for interest included: no β – agonist versus β – agonist and Ractopamine versus Zilpaterol. Treatment differences for the crude protein treatments were separated using the PDIFF option of the LSMEANS statement of SAS.

RESULTS AND DISCUSSION

Steer Health

The health summary for steers used for the study is shown in Table 3.6. There were not enough health issues observed to effectively subject the data to statistical evaluation. Morbidity rate was 4.63% of all steers placed on the study. Respiratory pulls accounted for 77.5% of all treated steers. Of the 31 steers treated for respiratory issues, 4 were railed, and 3 were found dead for a 22.6% treatment failure rate. Death loss was 1.27% of all steers placed in the study. Three steers died of respiratory problems, 4 steers were determined to die from digestive problems, and 3 deaths were attributed to pen injuries.

Nutrient Analyses for Finishing Diets

The analyzed nutrient profile for the finishing diets used for the study is displayed in Table 3.7. Nutrient analysis for the pre-treatment diet was similar to formulated values and, by study design, not significantly different from the 13.5/3.5 diets for CP and NPN. Interactions between CP and BA treatments for all nutrients with the exception of potassium were not significant. Therefore, only the main effects on dietary nutrient concentration are shown. Treatment diets were not different for DM, ether extract, calcium, and magnesium. Beta-agonist treatment had no effect on all of the nutrients except potassium ($P < 0.0001$). The interaction between CP and BA treatment for potassium concentration was also significant ($P < 0.0001$). For some unknown reason, the 12.5/3.5 BA Control diet and the 12.5/3.5 with OPT diet had potassium concentrations of 0.99 and 1.01% of DM respectively compared with the remaining treatments that averaged between 0.62 and 0.67% potassium. Crude protein treatment had a significant impact on CP ($P < 0.001$), NPN ($P < 0.0001$), NDF

($P < 0.02$), phosphorus ($P < 0.01$), potassium ($P < 0.0001$), and sulfur ($P < 0.02$). Differences between CP treatments for CP and NPN were consistent with the design of the study. Neutral detergent fiber, phosphorus, and sulfur differences can be explained by the differences between treatments in DDG content. Dried distiller's grains contain significant concentrations of NDF, phosphorus, and sulfur. The 12.5/3.5 treatment diets contained no DDG while the remaining treatments had over 4% of DM as DDG. It is not known why the potassium concentration for the 12.5/3.5 treatment was greater than the remaining treatments.

Feedlot Performance and Carcass Merit

Interactions between BA and CP treatments were not significant ($P > 0.32$) for all performance and carcass variables that were analyzed. Therefore, only main effects are presented and discussed. However, with there being no significant interactions, it is safe to assume that feeding BA's in a steam-flaked corn based diet with only 11.5% CP and 1.5% NPN still provides desired improvements in ADG, HCW, LM area, F:G and G:F ratios, as well as decreases in USDA Yield Grade. While the aim of this study was not to identify minimum requirements of CP needed in rations including BA supplementation, results at the 11.5% CP 1.5% NPN treatment level appear to be adequate levels of CP and NPN to provide continued levels of feedlot performance and improvements from BA supplementation. Least squares means showing the effects of BA treatment on feedlot performance and carcass merit are shown in Tables 3.8 and 3.10, respectively. Tables 3.9 and 3.11 show least squares means illustrating the effect of CP treatment on feedlot performance and carcass merit, respectively. Raw means and standard errors for the individual treatment combinations for

feedlot performance are available in Appendices B, C, and D. Carcass merit raw means and standard errors are displayed in Appendices E, F, and G.

Despite attempts to equalize treatment starting weight, steers assigned to the Zilmax treatments were numerically 4.99 kg lighter than steers assigned to the Control and Optaflexx treatments. Steers assigned to the 12.5/3.5 CP treatments were numerically higher than steers assigned to the remaining CP treatments. Although these differences were not statistically significant, treatment start weight (slaughter minus 28 d) was used as a covariate for the analysis of feedlot performance and continuous carcass merit variables. Other covariates, including initial body weight at d 0 and DMI from d 0 through treatment initiation, were examined during the statistical analysis of the data. Conclusions drawn using these alternative covariates were not different than the conclusions drawn using treatment start weight as a covariate.

Beta - agonist Treatment

Body Weight and Average Daily Gain

Average slaughter weights for steers treated with BA were 6.30 kg heavier ($P < 0.01$) than control steers (Table 3.8). There was no difference between the slaughter weights for the OPT versus the ZIL steers. Average daily gains during the final 28 d were greater ($P < 0.01$) for steers fed BA as compared with Control steers. Average daily gain was similar for OPT and ZIL fed steers. These results are similar to those found by Averdano-Reyes et al. (2006) and Scramlin et al. (2010). Figure 3.1 compares body weight gain during the final 28 d prior to slaughter for steers fed Control, OPT, and ZIL. At any point in time, weight gain was similar for the OPT and ZIL treatments. However, the ZIL curve appears steeper

initially than the OPT curve, and it looks as if the ZIL curve reaches a plateau sooner than the OPT curve. Calculating the first derivative of the equations describing each curve, setting them equal to zero and solving for days suggests that maximum body weight gain is achieved by 32.5, 36.7, and 29.3 days for the Control, OPT, and ZIL treatments, respectively. Caution is warranted when extrapolating the results of the current study beyond the 20-d ZIL or 28-d OPT programs evaluated. Studies directly comparing the growth curves of these products beyond the industry standard 28-d OPT and 20-d ZIL feeding programs are not readily available. There was a tendency ($P < 0.12$) for ADG advantages for the BA treatments to be detected from d 1 through slaughter. These results were also consistent with Winterholler et al. (2007) and Abrey et al. (2007).

Daily Dry Matter Intake

Beta-agonist treatment had no effect ($P > 0.3695$) on daily dry matter intake. Average DMI for the final 28d of the finishing period was 9.163 kg, 9.262 kg, and 9.004 kg for control, OPT and ZIL treatments, respectively. This finding is consistent with the general thought in the industry that Optaflexx and Zilmax generally have no effect on feed intake. However, there are some instances where intake effects were noted.

Feed Efficiency

Average daily gain during the final 28 d for pens 304 (no BA), 307 (no BA), and 404 (OPT) were -0.0036, -0.16, and -0.018 $kg \cdot hd^{-1} \cdot d^{-1}$, respectively. Average daily gain for an additional 28 pens enrolled in the study were less than 0.454 $kg \cdot hd^{-1} \cdot d^{-1}$. As a result of these negative values and values that approached zero, non-sensible feed-to-gain ratios (F:G) were

calculated for the last 28 d prior to slaughter. Therefore, F:G data could not be subjected to statistical analysis, and F:G values shown in Table 3.8 for the final 28 d were calculated from mean DMI and ADG for each BA treatment. Feed-to-gain ratio was improved by 25% for steers fed BA during the final 28 d as compared with controls. The 3.3% advantage in F:G from d 1 through slaughter for steers fed BA ($P < 0.01$) as compared with controls was statistically significant ($P < 0.01$).

Gain-to-feed ratio (G:F) data for the final 28 d are displayed as kg gain per 45.36 kg dry matter and were subjected to statistical analysis. More than a 35% improvement ($P < 0.001$) in G:F over the final 28 d of the feeding period was observed for steers fed BA as compared with controls. Differences between OPT and ZIL were not significant. The advantage in G:F for the BA treatments as compared to controls (3.4%) was detected from d 1 through slaughter ($P < 0.01$). Montgomery et al. (2008) found similar results with ZIL increasing G:F by 28%.

Net Energy Recovery

Net energy for maintenance and gain recovery for the final 28 d on feed could not be computed due to negative ADG for 3 pens. Net energy recovery values shown in Table 3.8 were calculated from mean ADG and DMI for each of the BA treatments. Net energy recovery was increased 19% during the final 28 d on feed for steers fed BA as compared with control. The advantage in NEm and NEg recovery for steers fed OPT or ZIL was detected from d1 through slaughter ($P < 0.01$).

Carcass Merit

Least squares means for HCW, adjusted for live weight at treatment initiation, was 9.21 kg heavier ($P < 0.01$) for ZIL steers as compared with controls. The advantage ($P < 0.05$) in HCW for ZIL as compared with OPT was 5.81 kg. Although not statistically significant, the numerical advantage in HCW for OPT steers as compared with control steers was 3.40 kg. The 9.21 kg advantage in HCW for ZIL steers versus control was 155% of the increase in adjusted slaughter weight for ZIL versus controls. The study design did not call for an initial slaughter group at the time of treatment initiation. Therefore, HCW at the time of treatment initiation is not known, and the actual contribution of HCW gain as a proportion of live weight gain cannot be calculated. The likelihood that an individual carcass within a pen weighed more than 408.23 kg was not affected by BA ($P = 0.33$). There were significantly more ($P < 0.05$) ZIL than OPT carcasses that weighed more than 430.91 kg; however, differences between control versus ZIL ($P > 0.28$) and control versus OPT ($P > 0.22$) were not significant. Overall, there was a numerical trend for increased heavies as would be expected from the increased HCW.

Dressing percentage was increased by an entire percentage unit for steers fed ZIL versus control ($P < 0.001$) and OPT ($P < 0.01$) but not increased for OPT versus control (63.2 versus 63.4%, $P = 0.67$). This increase in dressing percentage for ZIL carcasses explains why HCW was higher steers fed ZIL even though slaughter weights for OPT and ZIL steers were similar.

No BA treatment differences were observed for fat depth measured at the 12^{th} rib. Longissimus muscle area (LMA) was affected ($P < 0.0001$) by BA treatment. Longissimus muscle area for control carcasses (avg = 83.48 sq. cm.) was lower ($P < 0.06$) than LMA for

OPT carcasses (avg = 85.16 sq. cm.) which was in turn lower ($P < 0.01$) than LMA for ZIL carcasses (avg = 87.87 sq. cm.). Often LMA increases are simply a function of increased HCW. However, LMA per kg HCW was greater for ZIL carcasses compared with control ($P < 0.01$) or OPT ($P < 0.10$) carcasses suggesting that carcasses from steers fed ZIL were heavier muscled than carcasses from either the control or OPT treatments. Kidney, pelvic, and heart fat was lower for ZIL carcasses as compared with control ($P < 0.05$) or OPT ($P < 0.10$) carcasses.

Yield grades calculated from carcass measurements were similar for OPT and ZIL (3.01 versus 2.97, $P = 0.37$). Beta-agonist treatment reduced ($P < 0.05$) calculated yield grade as compared with the control treatment (avg = 3.12). Carcasses from OPT and ZIL treatments were more likely ($P < 0.05$) to qualify for the USDA Yield Grade 1 and 2 categories and less likely ($P < 0.05$) to qualify for the USDA Yield Grade 3 category as compared with control carcasses. There were no differences in the distribution of USDA Yield Grade 4 and 5 carcasses among control, OPT, and ZIL treatments.

Marbling score was similar for OPT and ZIL carcasses averaging Small^{11} and Small^{09}, respectively. Marbling score for the control carcasses was significantly higher ($P < 0.01$) than for BA and averaged a Small^{32} degree of marbling. The likelihood of an individual carcass within a pen of grading low Choice and above was reduced ($P < 0.01$) for the OPT (avg = 53.9%) and ZIL (avg = 49.7%) treatments as compared with controls (avg = 61.8%).

Crude Protein Withdrawal

There was a tendency ($P < 0.10$) for CP withdrawal treatment to impact slaughter weight, ADG during the final 28 d, and ADG d1 through slaughter. Slaughter weight, ADG during the final 28 d, and ADG d 1 through slaughter was lower for the 12.5/3.5 treatments as compared with the 12.5/2.5 ($P < 0.05$) and 11.5/1.5 ($P < 0.10$) treatments. Crude protein withdrawal treatment had no effect on HCW and all other carcass variables evaluated. Therefore, lower slaughter weight by the 12.5/3.5 treatment and the effect of this reduced weight on ADG were likely a function of reduced gut fill due to a reduction in DMI by steers fed the 12.5/3.5 diets during the final 28 d on feed as compared with the 13.5/3.5 ($P < 0.05$), 12.5/2.5 ($P < 0.01$), and 11.5/1.5 ($P < 0.10$) treatments.

The main difference in the 12.5/3.5 diet versus the remaining diets was the absence of DDG in the diet. Un-degradable intake protein comprises 72.8% of the CP concentration in DDG. The UIP concentration in the 12.5/3.5 diet was about 4.4% compared with greater than 5.2% for the remaining CP treatments. The DIP concentration of the 12.5/3.5 diets was approximately 8% versus 7.26 and 6.27% for the 12.5/2.5 and 11.5/1.5 diets yet DMI was lower. These results suggest that during the last 28 d on feed, DIP required maybe as low as 6.27% but UIP requirements may continue to be above 4.4% and maybe as high as 5.2%. It must also be noted that because DDG was withdrawn from the diet, the NDF and ADF concentrations in the 12.5/3.5 diet were lower which also may have contributed to lower intakes in this treatment.

Nitrogen Intake, Retention, and Excretion

The effects of BA and CP treatment on nitrogen (N) intake, retention, and excretion during the final 28 d are shown in Tables 3.12 and 3.13, respectively. Interactions between BA and CP treatment were not significant ($P > 0.90$); therefore, only main effects are shown. Because ADG was less than 0 for 3 pens, negative N retention values were generated for these 3 pens. The amount of N excreted due to weight loss was assumed to equal the negative N retention value calculated by the equations listed in Appendix H. Cumulative nitrogen intake for the final 28 d on feed was not affected by BA treatment ($P = 0.39$) and averaged 5,134; 5,192; and 5,041 g/hd for the Control, OPT, and ZIL treatments, respectively.

Nitrogen retention during the final 28 d on feed was greater ($P < 0.01$) for steers fed BA as compared with control and averaged 261 versus 356 and 348 g/hd for the Control, OPT, and ZIL treatments, respectively. These retention values were only 5.01, 6.79, and 6.83% of N intake for the Control, OPT, and ZIL treatments, respectively. The retention values for the current study apply to heavy yearling cattle and were calculated for only the final 28 d on feed. Average daily gain during the final 28 d for the current study was only 1.81 lb/d. If one assumes that body weight gain during this period was 100% lean tissue and that lean tissue is 27% DM of which 58% is CP, the theoretical maximum amount of N retained during the final 28 d could have been only 577 g. Thus, the theoretical maximum N retention value for cattle gaining 0.82 kg per day and consuming 9.07 kg of DM daily is only about 11.2% of N intake. Live weight gain during the final 28 d on feed is predominately fat. Thus N retention values of 5 to 6.8% of N intake during the final 28 d on feed are reasonable.

Nitrogen excretion was similar (P = 0.70) for Control and OPT steers (4,872 versus 4,836 g/hd) and greater (P < 0.06) for Control versus ZIL steers (4,872 versus 4,693 g/hd). There was a trend (P < 0.13) for lower N excretion for ZIL steers as compared with OPT steers. Nitrogen retention and excretion were calculated on a live weight basis in this study. Calculating N retention and excretion on a carcass weight basis would favor the ZIL treatment to even a greater extent than shown by the current calculations.

As expected, N intake during the final 28 d on feed was impacted by CP treatment (*P* < 0.0001). Nitrogen intake averaged 5,590; 4,960; 5,218; and 4,721 g/hd for the 13.5/3.5; 12.5/3.5; 12.5/2.5; and 11.5/1.5 CP treatments, respectively. Nitrogen intake was greater (*P* < 0.01) for the 13.5/3.5 versus the 12.5/2.5 treatment which was greater (*P* = 0.02) than N intake for the 12.5/3.5 treatment which in turn was greater (*P* < 0.11) than the 11.5/1.5 treatment.

There appeared to be few differences in N retention between CP treatments (*P* = 0.16), and average N retention for the 13.5/3.5, 12.5/3.5, 12.5/2.5, and 11.5/1.5 CP treatments was 315, 272, 365, and 335 g/hd, respectively. When N retention was expressed as a percentage of N intake, CP treatment affected (*P* < 0.08) N retention and N retention was 5.54, 5.43, 6.97, and 6.90% of N intake for the 13.5/3.5, 12.5/3.5, 12.5/2.5, and 11.5/1.5 CP treatments, respectively.

Nitrogen excretion per unit N intake for the 12.5/3.5 and 13.5/3.5 were similar (*P* = 0.88), but both were lower (*P* < 0.08) than N retention per unit N intake for the 11.5/1.5 and 12.5/2.5 CP treatments. Nitrogen excretion was 5,282; 4,654; 4,875; and 4,391 g/hd for the 13.5/3.5, 12.5/3.5, 12.5/2.5, and 11.5/1.5 CP treatments, respectively, and highly significant CP differences (*P* < 0.0001) were found. Nitrogen excretion was greatest (*P* < 0.001) for the

13.5/3.5 CP treatment as compared with the remaining treatments. Differences between the 12.5/3.5 versus 12.5/2.5 ($P < 0.05$) and between the 12.5/2.5 versus 11.5/1.5 ($P < 0.0001$) treatments were also significant.

Removing the DDG from the diet (CP treatment 12.5/3.5 versus 13.5/3.5) for the last 28 d reduced N intake (g/hd) by 12.0%, may have reduced N retention (g/hd) by 13.7%, and resulted in 11.9% reduced N excretion (g/hd). Using the 12.5/2.5 CP treatment diet in place of the 13.5/3.5 CP treatment diet reduced N intake by 6.4% and reduced N excretion by 7.7%. Using the 11.5/1.5 CP treatment diet versus the 13.5/3.5 CP treatment diet reduced N intake by 15.6% and N excretion by 16.9%. These changes in N intake, retention, and excretion were calculated using least squares means for each CP treatment and thus assumed that numerical performance differences were indeed real. If performance actually remained the same, as suggested by the statistical evaluation for the 12.5/2.5 and 11.5/1.5 CP treatments as compared with the 13.5/3.5 CP treatment, N retention would be the same for these treatments and N excretion during the final 28 d would be reduced by 6.8 and 16.6% for the 12.5/2.5 and 11.5/1.5 CP treatments, respectively.

The effect of OPT and ZIL on live weight performance appears similar. However, dressing percentage for steers fed ZIL was increased by approximately 1 percentage unit resulting in a 9.2 kg increase in HCW over the control treatment as compared with a 3.4 kg HCW increase as compared with controls for steers fed OPT. The effects of ZIL and OPT on quality and yield grade was similar.

Using the 12.5/2.5 or 11.5/1.5 CP treatment diets as compared with the 13.5/3.5 CP diet did not reduce feedlot performance, HCW, or USDA Quality and Yield Grade during the final 28 d. Total N intake over the entire 28 d was reduced by 358 and 872 g/hd for the

12.5/2.5 and 11.5/1.5 as compared with the 13.5/3.5 CP treatments, respectively (Table 3.13). These N intake differences amount to 79.83 (88 tons) and 194.14 metric tons (214 tons) of urea per 100,000 hd finished using the 12.5/2.5 and 11.5/1.5 programs, respectively. If urea was valued at $330.69 per metric ton ($300 per ton), the total savings per 100,000 head finished by a commercial feedyard would be $28,992 ($26,301) for using the 12.5/2.5 diet and $70,617 ($64,063) for using the 11.5/1.5 diet as compared with using the 13.5/3.5 CP treatment diet during the last 28 d on feed. For each $110 per metric ton increase in urea price ($100 per ton), the savings increases by $9,664 ($8,767) and $23,539 ($21,354) per 100,000 hd finished for the 12.5/2.5 and 11.5/1.5 diets, respectively. On an annualized basis, these savings should be multiplied by an individual feedyard's turnover rate.

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APPENDICES AND TABLES

Table 3.1. Cattle sources used for the crude protein and beta-agonist study.

Hd	Arrival Date	Off-truck Weight, kg	Average O-T Weight, kg	Pay-weight, kg	Average Pay-weight, kg	Shrink %	Origin
118	9/26/08	41,639.78	352.90	44,786.80	379.66	7.03	Uniontown, AL
60	10/01/08	22,697.76	378.30	24,146.54	402.34	6.00	Sidney, AR
62	10/01/08	23,360.01	376.94	24,782.02	399.66	5.74	Cave Spring, AR
126	10/01/08	49,033.34	389.18	48,843.73	387.82	-0.39	Springfield, CO
186	10/02/08	64,736.70	347.91	67,691.40	363.78	4.36	Centralia, OK
57	10/08/08	19,685.91	345.18	20,416.65	358.34	3.58	Roosevelt, UT
57	10/09/08	20,638.45	361.97	21,652.69	379.66	4.68	Oltonah, UT
57	10/09/08	21219.05	372.40	21,763.82	381.92	2.50	Altavista, KS
59	10/09/08	20,184.86	342.01	21,861.34	370.59	7.67	Whiteville, KS
129	10/09/08	45,976.12	356.52	48,611.49	376.94	5.42	Mt. Vernon, TX
117	10/10/08	40,904.96	349.72	44,442.98	379.66	7.96	Uniontown, AL
63	10/12/08	22,353.03	354.71	22,778.96	361.55	1.87	Ashdown, AR
1091		372,744.10	360.61	391,361.80	358.79	4.76	

Table 3.2. Dry matter ingredient and theoretical nutrient composition of the starter and step-up diets used for the crude protein and beta-agonist study.

Item[a]	Starter	Step-one	Step-two
Ingredient			
Corn silage	31.295	26.603	23.621
Steam-flaked corn	36.722	48.562	60.324
Alfalfa hay	23.548	15.000	5.000
Soybean meal – 49%	3.757	3.493	2.911
Yellow Grease		1.000	2.000
Corn Steep[b]	3.000	3.000	3.000
Supplement[c]	1.678	2.342	3.144
Theoretical nutrients			
Dry matter, % of as-fed	55.781	58.256	59.800
Crude protein	13.500	13.500	13.500
Non-protein nitrogen[d]	0.750	1.500	2.500
NEm[e], Mcal/kg DM	18,642.07	19,915.9	21,219.27
NEg[f]Mcal/kg DM	11,910.69	13,051.37	14,210.12
Acid detergent fiber	18.181	14.103	9.888
Neutral detergent fiber	27.646	22.691	17.704
Crude fiber	15.570	12.330	9.128
fNDF[g]	24.000	18.000	12.000
Ether Extract	3.187	4.324	5.496
Calcium	0.700	0.700	0.700
Phosphorus	0.308	0.315	0.318
Potassium	1.303	1.081	0.833
Magnesium	0.310	0.310	0.310
Sulfur	0.200	0.186	0.168

[a] Percentage of dry matter unless stated otherwise.
[b] Condensed Corn Steep Liquor.
[c] See Table 3.4 for supplement composition.
[d] Crude protein equivalent basis.
[e] Net energy for maintenance.
[f] Net energy for gain.
[g] Neutral detergent fiber provided by the forage in the diet.

Table 3.3. Dry matter ingredient and theoretical nutrient composition of the finishing diets used for the crude protein and beta-agonist study.

Item[a]	CP[b] 13.5% NPN[c] 3.5%	CP 12.5% NPN 3.5%	CP 12.5% NPN 2.5%	CP 11.5% NPN 1.5%
Ingredient				
Corn silage	14.531	14.531	14.531	14.531
Steam-flaked corn	71.432	74.544	71.952	72.472
Dried distiller's grains	4.627		4.453	4.280
Yellow Grease	3.354	3.834	3.364	3.373
Corn Steep[d]	2.000	2.000	2.000	2.000
Supplement[e]	4.056	5.091	3.700	3.344
Theoretical nutrients				
Dry matter, % of as-fed	66.594	66.369	66.536	66.479
Crude protein	13.500	12.500	12.500	11.500
Non-protein nitrogen[f]	3.500	3.500	2.500	1.500
DIP[g]	8.251	8.053	7.260	6.269
UIP[h]	5.249	4.447	5.240	5.231
NEm[g], Mcal/kg DM	22,275.07	22,377.36	22,364.79	22,454.74
NEg[h], Mcal/kg DM	15,234.16	15,349.46	15,297.88	15,360.27
Acid detergent fiber	6.678	5.939	6.662	6.647
Neutral detergent fiber	14.463	13.469	14.466	14.469
Crude fiber	6.042	5.662	6.038	6.034
fNDF[i]	6.000	6.000	6.000	6.000
Ether Extract	7.500	7.500	7.500	7.500
Calcium	0.700	0.700	0.700	0.700
Phosphorus	0.321	0.287	0.321	0.321
Potassium	0.700	1.150	0.700	0.7000
Magnesium	0.310	0.310	0.310	0.310
Sulfur	0.173	0.250	0.173	0.172

[a] Percentage of dry matter unless stated otherwise.
[b] Crude protein.
[c] Non-protein nitrogen
[d] Condensed Corn Steep Liquor.
[e] See Table 3.5 for supplement composition.
[f] Crude protein equivalent basis.
[g] Net energy for maintenance.
[h] Net energy for gain.
[i] Neutral detergent fiber provided by the forage in the diet.

Table 3.4. As-fed ingredient composition of the starter and step-up supplements used for the crude protein and beta-agonist study.

Ingredient[a]	Starter	Step-one	Step-two
Urea	12.080	21.834	26.480
Limestone	11.090	9.642	20.399
Min Ad[b]	53.976	49.988	39.336
Salt	14.521	11.359	7.999
Mineral Oil	2.000	1.995	1.997
Trace mineral premix[c]	4.647	3.635	2.560
Vitamin A premix[d]	0.174	0.136	0.096
Vitamin E premix[e]	0.968	0.757	0.534
Rumensin 80[f]	0.544	0.426	0.440
Tylan 100[g]		0.227	0.160

[a]Percentage of as-fed.
[b] Min Ad Inc., Amarillo, TX. 21.45% Ca and 11.68% Mg, dry matter basis.
[c]TM premix: Co, 500 ppm; Cu, 2.5%; Mn, 6.25%; Zn, 18.75%; I, 630 ppm; and Se, 300 ppm.
[d] 110,231,131.09 IU vitamin A activity per kg.
[e] 198,416.04 IU vitamin E activity per kg.
[f] Monensin, 176.37g per kg.
[g] Tylosin, 220.46g per kg.

Table 3.5. As-fed ingredient composition of the finishing diet supplements used for the crude protein and beta-agonist study.

Ingredient[a]	CP[b] 13.5% NPN[c] 3.5%	CP 12.5% NPN 3.5%	CP 12.5% NPN 2.5%	CP 11.5% NPN 1.5%
Urea	29.210	23.555	22.653	14.708
Limestone	17.839	13.116	19.549	21.620
Min Ad[d]	36.421	30.654	39.883	44.078
Salt	6.133	4.890	6.720	7.432
Potassium chloride	5.151	23.195	5.638	6.229
Mineral Oil	2.243	2.194	2.266	2.294
Trace mineral premix[e]	1.963	1.565	2.151	2.378
Vitamin A premix[f]	0.049	0.039	0.054	0.059
Vitamin E premix[g]	0.409	0.326	0.448	0.495
Rumensin 80[h]	0.460	0.367	0.504	0.557
Tylan 100[i]	0.123	0.098	0.135	0.148

[a] Percentage of as-fed.
[b] Crude protein.
[c] Non-protein nitrogen
[d] Min Ad Inc., Amarillo, TX. 21.45% Ca and 11.68% Mg, dry matter basis.
[e] TM premix: Co, 500 ppm; Cu, 2.5%; Mn, 6.25%; Zn, 18.75%; I, 630 ppm; and Se, 300 ppm.
[f] 110,231,131.09 IU vitamin A activity per kg.
[g] 198,416.04 IU vitamin E activity per kg.
[h] Monensin, 176.37g per kg.
[i] Tylosin, 220.46g per kg.

Table 3.6. Cattle health summary the crude protein and beta-agonist finishing diet study.

Date	Steer	Pen	Trt[a]	ºC	SC[b]	Diagnosis	Outcome
10/11/08	61012	307	1	39.72	4	Respiratory	Recovered
10/13/08	61171	523	9	40.11	3	Respiratory	Recovered
10/15/08	61219	304	2	40.00	5	Respiratory/Lameness	Recovered
10/15/08	60514	310	2	39.83	5	Respiratory	Recovered
10/15/08	60926	404	8	40.17	3	Lameness/Foot Rot	Recovered
10/15/08	60822	408	10	39.89	3	Respiratory	Recovered
10/15/08	60826	408	10	39.89	5	Respiratory	Recovered
10/15/08	60827	408	10	39.72	5	Respiratory	Recovered
10/15/08	60339	421	7	40.06	3	Respiratory	Recovered
10/15/08	60544	507	5	40.06	5	Respiratory	Recovered
10/18/08	60285	622	10	40.22	-	Respiratory	Recovered
10/18/08	61189	625	7	40.00	-	Respiratory	Recovered
10/19/08	61154	216	3	40.28	-	Respiratory	Recovered
10/19/08	60268	427	2	40.61	-	Respiratory	Recovered
10/19/08	60677	521	1	40.39	-	Respiratory	Recovered
10/19/08	60575	528	7	40.00	-	Respiratory	Recovered
10/19/08	61272	628	5	40.17	-	Respiratory	Recovered
10/24/08	60869	125	8	40.06	4	Respiratory	Recovered
10/24/08	61155	216	3	39.72	1	Pink Eye	Recovered
10/24/08	61158	216	3	39.78	2	Pink Eye	Recovered
10/24/08	60758	219	7	40.11	3	Respiratory	Recovered
10/24/08	60158	222	4	39.89	1	Lameness/Foot Rot	Recovered
10/24/08	60927	225	5	40.22	4	Respiratory	Recovered
10/24/08	60764	228	12	39.83	5	Respiratory	Recovered
10/24/08	60926	404	8	-	-	Lameness/Foot Rot	Removed from study, railed
10/27/08	60753	219	7	40.17	4	Respiratory	Recovered
10/27/08	60754	219	7	40.00	4	Respiratory	Recovered
10/27/08	60755	219	7	39.89	2	Lameness/Foot Rot	Recovered
10/29/08	60175	526	6	40.06	4	Respiratory	Recovered
11/04/08	60557	215	10	39.83	3	Lameness/Foot Rot	Recovered
11/04/08	61184	624	3	-	-	Rupture	Removed from study, railed
11/08/08	60882	613	6	40.39	5	Respiratory	Recovered
11/08/08	60885	613	6	-	5	Respiratory/Lameness	Recovered
11/10/08	61035	415	10	-	-	Bloat/Clostridial Infection	Found in pen dead
11/17/08	60642	504	5	-	-	Respiratory	Found in pen dead
11/17/08	60284	622	10	39.89	5	Respiratory	Recovered
11/25/08	60563	127	12	-	2	Bloat	Recovered
11/25/08	60959	218	11	40.06	3	Respiratory	Re-treated on 12/03/08
11/25/08	60655	220	4	39.89	5	Respiratory	Recovered
11/26/08	61283	620	8	-	-	-	Found in pen dead
12/01/08	60861	125	8	-	-	Prolapse	Found in pen dead
12/03/08	60959	218	11	39.89	4	Respiratory	Recovered
12/08/08	60284	622	10	-	-	Respiratory	Found in pen dead
12/10/08	61085	621	12	-	-	Respiratory	Found in pen dead
12/15/08	60325	406	3	-	-	Bloat	Found in pen dead
12/18/08	60468	426	9	-	-	Bloat	Found in pen dead
12/25/08	60385	614	12	-	-	Bloat	Found in pen dead

12/25/08	61277	628	5	40.78	3	Respiratory	Recovered
12/29/08	60178	526	6	39.78	3	Respiratory	Recovered
01/08/09	60412	309	5	40.94	2	Respiratory	Railed
02/04/09	60563	127	12	-	-	Respiratory	Removed from study, railed
02/04/09	60412	309	5	-	-	Respiratory	Removed from study, railed
02/05/09	60414	309	5	-	-	Rupture	Removed from study, railed
02/16/09	60132	424	1	-	-	Lameness/Foot Rot	Removed from study, railed
03/05/09	61126	411	11	-	-	Lameness/Foot Rot	Removed from study, railed
03/10/09	60934	416	12	-	-	Respiratory	Removed from study, railed
03/19/09	60324	128	6	-	-	Pen injury	Found in pen dead
03/30/09	60279	524	9	-	-	Bloat	Found in pen dead

[a] Contol = Treatments 1, 2, 3, 4; Ractopamine hydrochloride = Treatments 5, 6, 7, 8; and Zilpaterol hydrochloride = Treatments 9, 10, 11, 12. Crude protein (CP) 13.5, Non-protein nitrogen (NPN) 3.5 = 1, 5, 9; CP 12.5, NPN 3.5 = 2, 6, 10; CP 12.5, NPN 2.5 = 3, 7, 11; and CP 11.5, NPN 1.5 = 4, 8, 12.

[b] Respiratory score – 1 point for each of the following symptoms: eye discharge, nasal discharge, depression, cough, and rapid breathing.

Table 3.7. Least square means describing finishing diet nutrition composition.

		Crude protein treatment					Beta-agonist treatment[h]			
Item[a]	Pre-treatment[b]	13.5/3.5[c]	12.5/3.5[d]	12.5/2.5[e]	11.5/1.5[f]	SEM[g]	Control	OPT	ZIL	SEM
Dry matter[i]	67.25 ± 0.68	67.17	67.45	67.29	67.06	0.54	67.02	67.18	67.53	0.47
Crude protein	13.37 ± 0.33	13.10	12.48	12.54	10.98	0.29	12.09	12.29	12.45	0.25
NPN[j]	3.47 ± 0.09	3.22	3.44	2.45	1.52	0.08	2.67	2.60	2.71	0.07
NDF[k]	13.57 ± 0.40	14.88	13.42	14.71	14.19	0.33	14.19	14.21	14.50	0.28
Ether Extract	7.66 ± 0.18	7.88	7.92	8.13	7.79	0.13	7.79	7.95	8.06	0.11
Calcium	0.72 ± 0.04	0.64	0.69	0.69	0.62	0.03	0.66	0.65	0.67	0.03
Phosphorus	0.32 ± 0.01	0.34	0.30	0.35	0.32	0.009	0.33	0.33	0.33	0.008
Potassium	0.62 ± 0.01	0.64	0.88	0.64	0.63	0.01	0.73	0.73	0.63	0.009
Magnesium	0.31 ± 0.02	0.32	0.32	0.32	0.30	0.01	0.32	0.31	0.32	0.01
Sulfur	0.20 ± 0.01	0.18	0.16	0.18	0.18	0.005	0.17	0.17	0.18	0.005

[a] Percentage of dry matter unless stated otherwise.
[b] Mean ± standard error of the mean.
[c] 13.5% crude protein (CP) and 3.5% crude protein equivalent (CPE) from NPN.
[d] 12.5% CP and 3.5% CPE from NPN.
[e] 12.5% CP and 2.5% CPE from NPN.
[f] 11.5% CP and 1.5% CPE from NPN.
[g] Standard error of the least squares mean.
[h] Control = no beta-agonist; OPT = 200 mg Optaflexx per head daily for 28 days; ZIL = 75 mg Zilmax per head daily for 20 days.
[i] Percentage of as-fed.
[j] Non-protein nitrogen.
[k] Neutral detergent fiber.

Table 3.8. Least square means showing the effects of beta-agonist treatment on feedlot performance.

Item	Beta-Agonist Treatment[a]			SEM	Prob > F
	Control	OPT	ZIL		
Initial weight, kg	347.04	350.45	344.4	7.67	0.2184
Treatment start wt.[b], kg	575.9	575.9	570.9	6.85	0.3067
Final wt.[c†,e†,f††], kg	593.1	599.8	598.9	2.68	0.0041
ADG[g], d1-trt start, kg	1.63	1.62	1.62	0.04	0.8005
ADG[c†,e†,f††], final 28d, kg	0.67	0.91	0.88	0.10	0.0041
ADG, d1-slaughter, kg	1.47	1.5	1.5	0.04	0.1186
DMI[h], d1-trt start, kg	9.15	9.09	8.95	0.21	0.1938
DMI, final 28d, kg	9.16	9.26	9.003	0.16	0.3695
DMI, d1-slaughter, kg	9.14	9.09	2.51	0.14	0.4208
F:G[i], d1-trt start	5.62	5.61	5.54	0.06	0.5766
F:G[j], final 28d	13.65	10.16	10.23		
F:G[c†,e*,f††], d1-slaughter	6.25	6.09	6.00	0.07	0.0108
G:F[k], d1-trt start	17.84	17.89	18.10	0.19	0.5855
G:F[c††,e†,f††], final 28d	7.12	9.73	9.59	0.96	0.0018
G:F[c†,e**,f††], d1-slaughter	16.04	16.47	16.70	0.20	0.0120
NEm[l], d1-trt start	23,212.47	23,375.61	23,441.75	0.86	0.6791
NEm[j], final 28d	17,273.22	19,623.35	19,771.06		
NEm[c†,e**,f††], d1-slaughter	22,055.04	22,615.02	22,786.98	0.82	0.0062
NEg[m], d1-trt start	16,254.68	16,397.98	16,457.51	0.76	0.6791
NEg[j], final 28d	11,049.57	13,108.69	13,238.76		
NEg[c†,e**,f††], d1-slaughter	15,240.56	15,732.19	15,882.10	0.72	0.0062

[a] Control = no beta-agonist; OPT = Optaflexx fed at 200 mg per head daily for 28 d; ZIL = Zilmax fed at 75 mg per head daily for 20d.

[b] Live weight at the start of beta-agonist treatment used as a covariate to analyze performance during the final 28 d and from d 1 through slaughter.

[c] Control versus beta-agonist.

[d] Optaflexx versus Zilmax, NS for all variables evaluated.

[e] Control versus Optaflexx.

[f] Control versus Zilmax.

[g] Average daily gain.

[h] Daily dry matter intake.

[i] Feed/gain; DMI kg/ADG kg

[j] Calculated from mean ADG and mean DMI due to negative ADG for 1 pen. Statistical evaluation not possible.

[k] Gain/feed; ADG kg/ DMI kg.

[l] Net energy for maintenance recovered from the diet, Mcal/kg dry matter.

[m] Net energy for gain recovered from the diet, Mcal/kg dry matter.

[*] $P < 0.10$; [**] $P < 0.05$; [†] $P < 0.01$; [††] $P < 0.001$; [†††] $P < 0.0001$.

Table 3.9. Least square means showing the effects of crude protein treatments on feedlot performance.

	Crude Protein Treatment[a]					
Item	13.5/3.5	12.5/3.5	12.5/2.5	11.5/1.5	SEM	Prob > F
Initial weight, kg	347.5	349.9	344.5	347.3	7.80	0.6091
Treatment start wt.[b], kg	573.7	576.7	572.7	573.9	6.99	0.8219
Final wt.[f**,g*], kg	596.8	593.8	600.1	598.3	2.8	0.0805
ADG[i], d1-trt start, kg	1.62	1.62	1.63	1.62	0.04	0.9774
ADG [f**,g*], final 28d, kg	0.81	0.70	0.93	0.86	0.09	0.0805
ADG [f**,g*], d1-slghtr, kg	1.48	1.46	1.51	1.50	0.04	0.0839
DMI[j], d1-trt start, kg	8.99	8.99	9.14	9.12	0.22	0.5578
DMI[c**,f†,g*], final 28d, kg	9.25	8.79	9.36	9.17	0.18	0.0480
DMI, d1-slaughter, kg	9.04	8.93	9.19	9.14	0.15	0.1476
F:G[k], d1-trt start	5.56	5.55	5.62	5.63	0.03	0.7883
F:G[l], final 28d	11.46	12.58	10.11	10.69		
F:G, d1-slaughter	6.11	6.14	6.08	6.13	0.04	0.9368
G:F[m], d1-trt start	18.05	18.05	17.86	17.81	0.09	0.8058
G:F, final 28d	8.54	7.79	9.83	9.09	0.46	0.1585
G:F, d1-slaughter	16.43	16.35	16.48	16.36	0.09	0.9486
NEm[n], d1-trt start	23,477.03	23,540.96	23,152.95	23,203.65	1.00	0.5117
NEm[l], final 28d	18,543.08	18,205.77	19,590.28	19,228.72		
NEm, d1-slaughter	22,544.47	22,487.15	22,473.92	22,436.44	0.92	0.9824
NEg[o], d1-trt start	16,488.37	16,543.49	16,203.98	16,248.07	0.88	0.5117
NEg[l], final 28d	12,160.70	11,865.28	13,080.03	12,762.56		
NEg, d1-slaughter	15,670.46	15,619.75	15,608.73	15,575.66	0.81	0.9824

[a] 13.5/3.5 = 13.5% crude protein (CP), 3.5% crude protein equivalent (CPE) from non-protein nitrogen (NPN); 12.5/3.5 = 12.5% CP, 3.5% CPE from NPN; 12.5/2.5 = 12.5% CP, 2.5% CPE from NPN; 11.5/1.5 = 11.5% CP, 1.5% CPE from NPN.

[b] Live weight at the start of beta-agonist treatment used as a covariate to analyze performance during the final 28 d and from d 1 through slaughter.

[c] 13.5/3.5 versus 12.5/3.5.

[d] 13.5/3.5 versus 12.5/2.5, NS for all variables evaluated.

[e] 13.5/3.5 versus 11.5/2.5, NS for all variables evaluated.

[f] 12.5/3.5 versus 12.5/2.5.

[g] 12.5/3.5 versus 11.5/1.5.

[h] 12.5/2.5 versus 11.5/1.5, NS for all variables evaluated.

[i] Average daily gain.

[j] Daily dry matter intake.

[k] Feed/gain; DMI kg/ADG kg.

[l] Calculated from mean ADG and mean DMI due to negative ADG for 1 pen. Statistical evaluation not possible.

[m] Gain/feed; ADG kg/kg DMI.

[n] Net energy for maintenance recovered from the diet, Mcal/kg dry matter.

[o] Net energy for gain recovered from the diet, Mcal/kg dry matter.

[*] $P < 0.10$; [**] $P < 0.05$; [†] $P < 0.01$; [††] $P < 0.001$; [†††] $P < 0.0001$.

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Table 3.10. Least square means showing the effects of beta-agonist treatment on carcass performance.

	Beta-Agonist Treatment[a]				
Item[b]	Control	OPT	ZIL	SEM	Prob > F
HCW[c,d†,e**,g†], kg	375.3	378.7	384.5	4.00	0.0017
HCW category[h]					
272 – 407 kg	80.74	78.81	76.00	6.69	0.4134
408 – 430 kg	13.48	18.03	15.40	4.04	0.3298
431 – 453 kg[e**,f*]	4.20	1.90	6.22	2.59	0.0345
≥ 454 kg[i]	1.07	1.43	1.07		
≥ 430 kg[d**]	4.78	3.00	6.73	2.92	0.0845
≥ 408 kg	18.96	21.24	24.05	6.62	0.3616
DP[c,e†,g**]	63.36	63.21	64.39	0.44	0.0103
Fat depth[c], cm.	1.27	1.19	1.24	0.03	0.3852
REA[c,d†††,e†,f**,g†††], cm.^{2}	83.49	85.17	87.88	0.90	<0.0001
KPH[d*,e*,g**], %	1.96	1.95	1.91	0.04	0.0491
Calc. YG[c,d**,f*,g**], units	3.12	3.01	2.97	0.04	0.0460
Marbling[d†,f†,g†], units	431.87	411.38	408.57	5.53	0.0051
Quality Grade Category[h]					
≥ Avg. Choice	8.44	5.50	4.57	2.32	0.1378
≥ Low Choice[d†,f*,g†]	61.78	53.93	49.70	3.55	0.0165
Select[d*,g**]	33.04	36.95	42.66	4.12	0.0665
Standard	2.80	6.09	4.58	1.73	0.1904
Yield Grade Category[h]					
YG 1 & 2[d**,f**,g**]	38.21	47.10	47.66	3.01	0.0439
YG 3[d**,f*,g**]	45.61	37.73	36.75	3.91	0.0690
YG 4 & 5	12.19	11.30	12.80	2.07	0.8609

42 [a] Control = no beta-agonist; OPT = Optaflexx fed at 200 mg per head daily for 28 d; ZIL =
43 Zilmax fed at 75 mg per head daily for 20 d.
44 [b] HCW = Hot carcass weight; DP = Dressing percentage; REA = Ribeye area; KPH = Kidney,
45 pelvic, and heart fat; Calc. YG = Yield grade calculated from carcass measurements; Marbling
46 units, 400= Small[00], 500 = Modest[00]; Marbling/Fat = Marbling units per 0.1 inch fat depth.
47 [c] Live weight at the start of beta-agonist treatment used as a covariate.
48 [d] Control versus beta-agonist.
49 [e] Optaflexx versus Zilmax.
50 [f] Control versus Optaflexx.
51 [g] Control versus Zilmax.
52 [h] Likelihood that an individual carcass within each pen qualified for a specific category.
53 [i] Carcasses weighing over 1000 lb are calculated as percentage of the total carcasses.
54 [*] P < 0.10; [**] P < 0.05; [†] P < 0.01; [††] P < 0.001; [†††] P < 0.0001.
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Table 3.11. Least square means showing the effects of crude protein treatments on carcass performance.

	Crude Protein Treatment[a]					
Item[b]	13.5/3.5	12.5/3.5	12.5/2.5	11.5/1.5	SEM	Prob > F
HCW[c], kg	379.7	378.4	381.1	378.8	4.12	0.7949
HCW category[d]						
272 – 407 kg	80.13	80.24	75.74	77.99	6.90	0.6589
408 – 430 kg	13.72	15.99	16.98	15.64	4.04	0.8168
431 – 453 kg	5.26	2.42	4.65	3.12	2.59	0.3760
≥ 454 kg[e]	0.00	1.43	1.42	1.92		
≥ 431 kg	4.97	3.60	5.54	4.51	2.56	0.7507
≥ 408 kg	19.93	19.81	23.74	22.06	6.73	0.7372
DP[c]	63.78	63.85	63.53	63.45	0.47	0.8015
Fat depth, cm.	1.24	1.24	1.22	1.24	0.05	0.9935
REA[c], cm.^{2}	85.42	85.30	86.07	85.36	0.97	0.8409
KPH, %	1.94	1.95	1.93	1.94	0.04	0.8541
Calc. YG[c], units	3.04	3.03	3.01	3.04	0.05	0.9666
Marbling, units	416.99	412.36	417.81	421.94	6.41	0.7699
Quality Grade Category[d]						
≥ Avg. Choice	7.12	5.46	5.99	5.47	2.26	0.8734
≥ Low Choice	56.91	54.79	53.40	55.67	3.95	0.9048
Select	35.32	36.87	39.33	38.40	4.39	0.8407
Standard	6.17	4.96	3.92	2.78	1.94	0.4168
Yield Grade Category[d]						
YG 1 & 2	45.01	44.23	46.08	41.80	3.48	0.8378
YG 3	41.11	37.83	36.60	44.50	4.30	0.3573
YG 4 & 5	10.87	13.56	13.14	10.98	2.45	0.7555

[a] 13.5/3.5 = 13.5% crude protein (CP), 3.5% crude protein equivalent (CPE) from non-protein nitrogen (NPN); 12.5/3.5 = 12.5% CP, 3.5% CPE from NPN; 12.5/2.5 = 12.5% CP, 2.5% CPE from NPN; 11.5/1.5 = 11.5% CP, 1.5% CPE from NPN.

[b] HCW = Hot carcass weight; DP = Dressing percentage; REA = Ribeye area; KPH = Kidney, pelvic, and heart fat; Calc. YG = Yield grade calculated from carcass measurements; Marbling units, 400= Small^{00}, 500 = Modest^{00}; Marbling/Fat = Marbling units per 0.1 inch fat depth.

[c] Live weight at the start of beta-agonist treatment used as a covariate.

[d] Likelihood that an individual carcass within a pen qualified for a specific category.

[e] Carcasses weighing over 1,000 lb are calculated as percentage of the total carcasses.

Table 3.12. Least squares means showing the effects of beta-agonist treatment on nitrogen intake, retention, and excretion during the final 28 d on feed.

Item	Control	Optaflexx	Zilmax	SEM	Prob. > F
Nitrogen intake, g/hd/[a]	5134	5192	5041	77	0.3856
Nitrogen retained, g/hd[b,c]	261	356	348	25	0.0173
Nitrogen retained, % of N intake[d]	5.01	6.79	6.83	0.47	0.0099
Nitrogen excreted, g/hd[f,g]	4872	4836	4693	66	0.1325
Reduction in excretion, %		0.7	3.7		

[a] 28 d x daily grams CP intake ÷ 6.25.
[b] Calculated as outlined in Appendix H.
[c] Control versus Optaflexx, P = 0.0103; Control versus Zilmax, P = 0.0180; Optaflexx versus Zilmax, P = 0.8404.
[d] Control versus Optaflexx, P = 0.0089; Control versus Zilmax, P = 0.0078; Optaflexx versus Zilmax, P = 0.9542.
[f] Control versus Optaflexx, P = 0.6997; Control versus Zilmax, P = 0.0576; Optaflexx versus Zilmax, P = 0.1273.
[g] Caution examining treatment differences is advised since differences shown are not from a Protected F Test. Overall probability for CP treatment equals 0.1325.

Table 3.13. Least squares means showing the effects of crude protein treatment on nitrogen intake, retention, and excretion during the final 28 d on feed.

Item	CP[a] 13.5% NPN[b] 3.5%	CP 12.5% NPN 3.5%	CP 12.5% NPN 2.5%	CP 11.5% NPN 1.5%	SEM	Prob > F
Nitrogen intake, g/hd/[c]	5,597[d]	4,926[e]	5,239[f]	4,725[f]	89	< 0.0001
Nitrogen retained, g/hd[h,i]	315[de]	272[d]	365[e]	335[de]	29	0.1589
Nitrogen retained, % of N intake	5.54[j]	5.43[j]	6.97[k]	6.90[k]	0.54	0.0749
Nitrogen excreted, g/hd[l]	5,282[d]	4,654[f]	4,875[e]	4,391[g]	76	< 0.0001
Reduction in excretion, %		11.9	7.7	16.9		

[a] Crude protein.
[b] Non-protein nitrogen.
[c] 28 d x daily grams CP intake ÷ 6.25.
[defg] LSMeans in same row with different superscripts differ P < 0.05.
[h] Calculated as outlined in Appendix H.
[i] Caution examining treatment differences is advised since differences shown are not from a Protected F Test. Overall probability for CP treatment equals 0.1589.
[jk] LSMeans in same row with different superscripts differ P < 0.08.
[l] Nitrogen intake – nitrogen retained.
[g] Since performance differences were not significant for the 12.5/2.5 and 11.5/1.5 CP treatments as compared with the 13.5/3.5 CP treatment, equal nitrogen retention was assumed and nitrogen excretion is a function of differences in nitrogen intake.

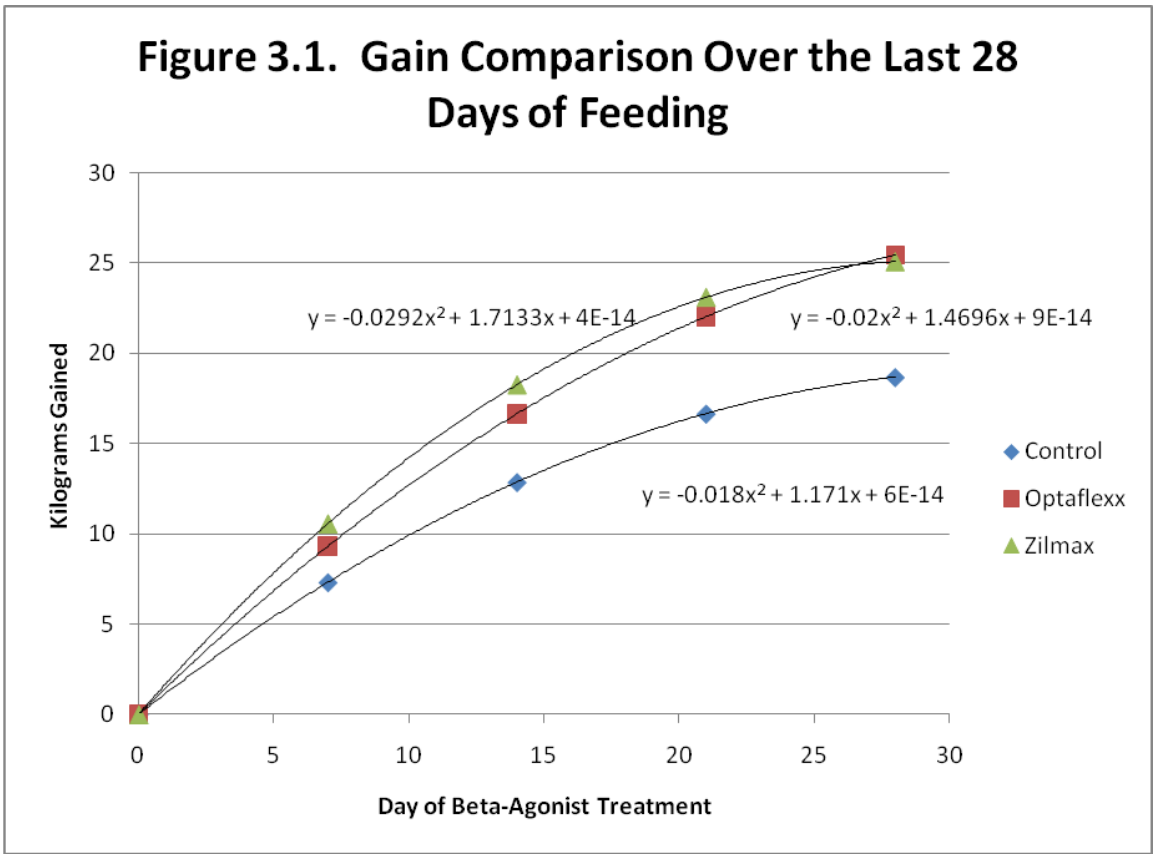
Figure 3.1. Gain Comparison Over the Last 28 Days of Feeding
Kilograms Gained
Day of Beta-Agonist Treatment
y = -0.0292x² + 1.7133x + 4E-14
y = -0.02x² + 1.4696x + 9E-14
y = -0.018x² + 1.171x + 6E-14
Control
Optaflexx
Zilmax
0
5
10
15
20
25
30

99

Appendix A

Energy Recovery. Net energy values for each diet were calculated from estimates of energy expended for maintenance (EM, Mcal/d) and energy retained (EG, Mcal/d) derived from BW, actual growth performance data, and DMI using the following equations for medium-framed yearling steers (NRC, 2000):

EM = 0.077 × mean shrunk $BW^{0.75}$ (kg), where shrunk BW (SBW) = full BW × 0.96;

EG = (0.0557 × ($SBW^{0.75}$) × (shrunk weight $gain^{1.097}$)), where shrunk weight gain (kg/d) is the shrunk daily weight gain.

The NEm and NEg values of the diets were then calculated using the solution for the quadratic equation:

NEm (Mcal/kg DM) = $((-b + \sqrt{(b^2-4ac)}) / 2a)$, where

a = 0.877 × DMI,

b = (-0.877 × EM) - (0.41* DMI) - EG, and

c = 0.41 × EM

NEg (Mcal/kg DM) = 0.877 x NEm - 0.41.

Appendix B

Effects of crude protein withdrawal on feedlot performance for steers receiving no beta-agonist.

	Crude Protein Treatments			
Item[a]	13.5/3.5	12.5/3.5	12.5/2.5	11.5/1.5
Initial weight, kg	351.04 ± 9.34	346.7 ± 9.30	347.5 ± 9.07	342.6 ± 10.5
Treatment start wt., kg	579.01 ±5.72	578.01 ± 6.21	575.3 ± 7.89	571.3 ± 10.8
Final wt., kg	595.7 ± 8.71	592.3 ± 8.89	597.8 ± 9.71	593.3 ± 12.02
ADG[b], d1-trt start, kg	1.64 ± 0.04	1.63 ± 0.05	1.64 ± 0.04	1.63 ± 0.06
ADG, final 28d, kg	0.59 ± 0.15	0.51 ± 0.14	0.80 ± 0.14	0.78 ± 0.12
ADG, d1-slaughter, kg	1.47 ± 0.05	1.45 ± 0.05	1.50 ± 0.05	1.48 ± 0.06
DMI[c], d1-trt start, kg	9.21 ± 0.21	9.01 ± 0.15	9.24 ± 0.23	9.15 ± 0.26
DMI, final 28d, kg	9.28 ± 0.22	8.90 ± 0.28	9.40 ± 0.34	9.24 ± 0.41
DMI, d1-slaughter, kg	9.23 ± 0.20	8.99 ± 0.15	9.27 ± 0.24	9.17 ± 0.28
F:G[d], d1-trt start	5.63 ± 0.10	5.54 ± 0.11	5.65 ± 0.09	5.65 ± 0.09
F:G, final 28d	6.75 ± 8.81	17.53[e]	15.77 ± 3.86	18.18 ± 6.90
F:G, d1-slaughter	6.33 ± 0.13	6.26 ± 0.16	6.20 ± 0.08	6.20 ± 0.08
G:F[f], d1-trt start	17.79 ± 0.31	18.10 ± 0.37	17.73 ± 0.29	17.74 ± 0.27
G:F, final 28d	6.26 ± 1.48	5.50 ± 1.50	8.45 ± 1.34	8.23 ± 1.16
G:F, d1-slaughter	15.85 ± 0.33	16.05 ± 0.41	16.14 ± 0.20	16.14 ± 0.21
NEm[g], d1-trt start	23,247.75 ± 282.19	23,536.55 ± 343.92	23,055.94 ± 154.32	23,007.44 ± 385.81
NEm, final 28d	17,374.63 ± 965.62	15,998.94[e]	18,241.05 ± 1,261.04	18,179.32 ± 804.69
NEm, d1-slaughter	21,966.86 ± 363.76	22,160.87 ± 421.08	22,136.62 ± 169.76	22,085.91 ± 291.01
NEg[h], d1-trt start	16,287.75 ± 249.12	16,539.08 ± 302.03	16,118.0 ± 134.48	16,076.11 ± 337.31
NEg, final 28d	11,135.55 ± 846.58	9,929.62[e]	11,896.14 ± 1,106.72	11,843.23 ± 705.48
NEg, d1-slaughter	15,165.6 ± 319.67	15,333.15 ± 370.38	15,311.1 ± 147.71	15,269.22 ± 255.74

[a] Raw pen means ± standard error of the mean.
[b] Average daily gain.
[c] Daily dry matter intake.
[d] Feed/gain; DMI kg/ADG kg.
[e] Calculated from mean ADG and mean DMI due to negative ADG for 1 pen.
[f] Gain/feed; ADG kg/DMI kg.
[g] Net energy for maintenance recovered from the diet, Mcal/kg dry matter.
[h] Net energy for gain recovered from the diet, Mcal/kg dry matter.

Appendix C

Effects of crude protein withdrawal on feedlot performance for steers receiving Optaflexx.

	Crude Protein Treatments			
Item[a]	13.5/3.5	12.5/3.5	12.5/2.5	11.5/1.5
Initial weight, kg	345.09 ± 8.48	358.5 ± 8.66	349.5 ±7.48	348.7 ± 7.8
Treatment start wt., kg	573.3 ± 8.66	582 ± 8.98	575.5 ± 6.94	573.0 ± 9.25
Final wt., kg	600.2 ± 9.71	605.9 ± 9.75	602.05 ± 7.57	598.2 ± 12.4
ADG[b], d1-trt start, kg	1.63 ± 0.05	1.62 ± 0.04	1.62 ± 0.04	1.61 ± 0.06
ADG, final 28d, kg	0.96 ± 0.11	0.85 ± 0.15	0.95 ± 0.11	0.90 ± 0.19
ADG, d1-slaughter, kg	1.51 ± 0.05	1.50 ± 0.04	1.51 ± 0.04	1.49 ± 0.07
DMI[c], d1-trt start, kg	8.92 ± 0.35	9.12 ± 0.15	9.08 ± 0.30	9.22 ± 0.20
DMI, final 28d, kg	9.40 ± 0.47	9.20 ± 0.20	9.47 ± 0.19	9.15 ± 0.40
DMI, d1-slaughter, kg	8.99 ± 0.35	9.14 ± 0.15	9.14 ± 0.27	9.21 ± 0.22
F:G[d], d1-trt start	5.47 ± 0.14	5.62 ± 0.11	5.59 ± 0.11	5.77 ± 0.16
F:G, final 28d	10.59 ± 1.09	18.46 ± 7.98	11.05 ± 1.36	10.14[e]
F:G, d1-slaughter	5.93 ± 0.14	6.13 ± 0.12	6.07 ± 0.14	6.24 ± 0.16
G:F[f], d1-trt start	18.35 ± 0.51	17.83 ± 0.38	17.95 ± 0.37	17.42 ± 0.50
G:F, final 28d	10.18 ± 1.05	9.17 ± 1.53	9.95 ± 1.07	9.58 ± 1.88
G:F, d1-slaughter	16.93 ± 0.42	16.37 ± 0.36	16.55 ± 0.38	16.11 ± 0.41
NEm[g], d1-trt start	23,748.19 ± 595.25	23,518.91 ± 456.36	23,393.25 ± 299.83	22,839.89 ± 522.5
NEm, final 28d	19,947.43 ± 1,014.13	19,191.24 ± 1,406.55	19,618.94 ± 961.22	19,700.51[e]
NEm, d1-slaughter	23,014.06 ± 533.52	22,712.02 ± 473.99	22,652.5 ± 352.74	22,213.78 ± 498.24
NEg[h], d1-trt start	16,724.27 ± 522.5	16,525.85 ± 399.04	16,415.62 ± 262.35	15,928.4 ± 456.36
NEg, final 28d	13,393.08 ± 888.46	12,729.49 ± 1,234.59	13,104.28 ± 844.37	13,177.03[e]
NEg, d1-slaughter	16,080.52 ± 467.38	15,815.96 ± 414.47	15,765.26 ± 310.85	15,379.45 ± 438.72

[a] Raw pen means ± standard error of the mean.
[b] Average daily gain.
[c] Daily dry matter intake.
[d] Feed/gain; DMI kg/ADG kg.
[e] Value for the 11.5/1.5 CP treatment calculated from mean ADG and mean DMI due to negative ADG for 1 pen.
[f] Gain/feed; ADG kg /DMI kg.
[g] Net energy for maintenance recovered from the diet, Mcal/kg dry matter.
[h] Net energy for gain recovered from the diet, Mcal/kg dry matter.

Appendix D

Effects of crude protein withdrawal on feedlot performance for steers receiving Zilmax.

	Crude Protein Treatments			
Item[a]	13.5/3.5	12.5/3.5	12.5/2.5	11.5/1.5
Initial weight, kg	346.4 ± 7.71	344.4 ± 9.57	336.5 ± 6.76	350.3 ± 9.71
Treatment start wt., kg	568.9 ± 6.80	569.9 ± 7.39	567.4 ± 10.2	577.6 ± 7.98
Final wt., kg	592.9 ± 10.6	590.71 ± 8.62	595.7 ± 11.4	602.5 ± 10.7
ADG[b], d1-trt start, kg	1.59 ± 0.04	1.61 ± 0.04	1.63 ± 0.07	1.64 ± 0.05
ADG, final 28d, kg	0.86 ± 0.15	0.74 ± 0.10	1.01 ± 0.11	0.89 ± 0.15
ADG, d1-slaughter, kg	1.47 ± 0.05	1.47 ± 0.04	1.52 ± 0.07	1.51 ± 0.06
DMI[c], d1-trt start, kg	8.86 ± 0.29	8.86 ± 0.24	9.09 ± 0.27	8.99 ± 0.31
DMI, final 28d, kg	9.04 ± 0.37	8.45 ± 0.30	9.08 ± 0.45	9.09 ± 0.34
DMI, d1-slaughter, kg	8.89 ± 0.29	8.79 ± 0.22	9.10 ± 0.29	9.004 ± 0.31
F:G[d], d1-trt start	2.52 ± 0.06	2.49 ± 0.03	2.54 ± 0.07	2.49 ± 0.041
F:G, final 28d	6.61 ± 1.87	5.79 ± 0.72	4.30 ± 0.34	5.96 ± 1.27
F:G, d1-slaughter	2.75 ± 0.05	2.73 ± 0.05	2.72 ± 0.05	2.70 ± 0.05
G:F[e], d1-trt start	8.17 ± 0.21	8.26 ± 0.11	8.11 ± 0.20	8.30 ± 0.14
G:F, final 28d	4.17 ± 0.61	3.93 ± 0.44	5.05 ± 0.49	4.30 ± 0.64
G:F, d1-slaughter	7.49 ± 0.14	7.56 ± 0.14	7.58 ± 0.13	7.62 ± 0.14
NEm[f], d1-trt start	23,435.14 ± 427.7	23,565.21 ± 240.3	23,007.44 ± 427.7	23,763.63 ± 156.53
NEm, final 28d	19,233.13 ± 1,150.81	19,202.26 ± 789.25	20,939.51 ± 965.62	19,618.94 ± 1135.38
NEm, d1-slaughter	22,621.63 ± 326.28	22,729.66 ± 286.6	22,544.47 ± 302.03	22,992.01 ± 231.49
NEg[g], d1-trt start	16,450.89 ± 374.79	16,565.53 ± 211.64	16,076.11 ± 374.79	16,739.7 ± 136.69
NEg, final 28d	12,764.76 ± 1,009.72	12,738.31 ± 692.25	14,261.7 ± 846.58	13,104.28 ± 994.28
NEg, d1-slaughter	15,738.8 ± 286.6	15,833.6 ± 251.33	15,670.46 ± 264.55	16,062.88 ± 202.83

[a] Raw pen means ± standard error of the mean.
[b] Average daily gain.
[c] Daily dry matter intake.
[d] Feed/gain; DMI kg/ADG kg.
[e] Gain/feed; ADG kg/DMI kg.
[f] Net energy for maintenance recovered from the diet, Mcal/kg dry matter.
[g] Net energy for gain recovered from the diet, Mcal/kg dry matter.

Appendix E

Effects of crude protein withdrawal on carcass performance for steers receiving no beta-agonist.

	Crude Protein Treatments			
Item[a]	13.5/3.5	12.5/3.5	12.5/2.5	11.5/1.5
Hot Carcass Weight, kg	374.8 ± 7.85	379.4 ± 6.96	376.03 ± 6.08	373.6 ± 7.80
Carcass weight category[b]				
272 – 407 kg	80.3	74.3	76.8	81.7
408 – 430 kg	14.1	18.6	17.4	9.9
431 – 453 kg	5.6	5.7	4.3	7.0
≥ 454 kg	0.0	1.4	1.4	1.4
≥ 431 kg	5.6	7.1	5.7	8.4
Dressing Percent	63.01 ± 0.86	64.28 ± 0.60	62.94 ± 1.09	62.97 ± 0.31
Fat depth, cm	1.24 ± 0.08	1.27 ± 0.08	1.30 ± 0.08	1.24 ± 0.05
Ribeye area, cm^2	84.45 ± 1.10	83.74 ± 0.58	83.42 ± 1.68	82.71 ± 1.03
KPH, %	2.01 ± 0.02	1.95 ± 0.04	1.95 ± 0.04	1.94 ± 0.04
Calculated YG, units[d]	3.04 ± 0.09	3.15 ± 0.08	3.17 ± 0.13	3.13 ± 0.06
Marbling, units[e]	430.3 ± 11.6	418.6 ± 12.8	444.0 ± 13.8	437.1 ± 10.6
Quality Grade Category[b]				
≥ Avg. Choice	11.3	10.3	7.4	8.6
≥ Low Choice	62.0	60.3	64.7	64.3
Select	33.8	35.3	32.4	34.3
Standard	4.2	4.4	2.9	1.4
Yield Grade Category[b]				
Yield Grade 1 & 2	46.4	40.3	37.3	34.3
Yield Grade 3	43.5	43.3	46.3	55.7
Yield Grade 4 & 5	10.1	16.4	14.9	10.0

[a] Raw pen mean ± standard error of the mean unless stated otherwise.
[b] Percentage of individual carcasses.
[c] Ribeye area per cwt hot carcass weight.
[d] Yield grade calculated from carcass measurements.
[e] Marbling score units; $Slight^{00}$ = 300, $Small^{00}$ = 400; $Modest^{00}$ = 500.

Appendix F

Effects of crude protein withdrawal on carcass performance for steers receiving Optaflexx.

	Crude Protein Treatments			
Item[a]	13.5/3.5	12.5/3.5	12.5/2.5	11.5/1.5
Hot Carcass Weight, kg	379.3 ± 6.21	378.3 ± 6.89	382.3 ± 5.62	377.7 ± 8.80
Carcass weight category[b]				
272 – 407 kg	78.3	80.0	72.2	72.5
408 – 430 kg	17.4	15.7	20.8	24.6
431 – 453 kg	4.3	1.4	5.6	1.4
≥ 454 kg	0.0	2.9	1.4	1.4
≥ 431 kg	4.3	4.3	7.0	2.8
Dressing Percent	63.36 ± 0.94	62.51 ± 0.74	63.50 ± 0.27	63.23 ± 0.74
Fat depth, cm	1.22 ± 0.08	1.14 ± 0.03	1.19 ± 0.08	1.24 ± 0.05
Ribeye area, cm^2	84.71 ± 0.84	85.74 ± 1.35	85.81 ± 1.68	84.64 ± 1.42
KPH, %	1.94 ± 0.04	1.96 ± 0.04	1.93 ± 0.05	1.96 ± 0.03
Calculated YG, units[d]	3.07 ± 0.08	2.92 ± 0.07	3.00 ± 0.11	3.08 ± 0.08
Marbling, units[e]	409.7 ± 7.4	419.7 ± 12.1	407.3 ± 7.3	411.6 ± 6.0
Quality Grade Category[b]				
≥ Avg. Choice	5.9	7.5	5.6	6.0
≥ Low Choice	53.0	58.2	52.1	58.2
Select	38.2	35.8	42.3	35.8
Standard	8.8	6.0	5.6	6.0
Yield Grade Category[b]				
Yield Grade 1 & 2	44.1	54.5	50.0	46.3
Yield Grade 3	42.6	34.8	25.7	43.3
Yield Grade 4 & 5	11.8	10.6	14.3	10.4

[a] Raw pen mean ± standard error of the mean unless stated otherwise.
[b] Percentage of individual carcasses.
[c] Ribeye area per cwt hot carcass weight.
[d] Yield grade calculated from carcass measurements.
[e] Marbling score units; $Slight^{00}$ = 300, $Small^{00}$ = 400; $Modest^{00}$ = 500.

Appendix G

Effects of crude protein withdrawal on carcass performance for steers receiving Zilmax.

	Crude Protein Treatments			
Item[a]	13.5/3.5	12.5/3.5	12.5/2.5	11.5/1.5
Hot Carcass Weight, kg	384.6 ± 6.76	380.4 ± 5.08	383.1 ± 7.17	384.7 ± 6.58
Carcass weight category[b]				
272 – 407 kg	71.8	78.6	71.4	70.6
408 – 430 kg	14.1	17.1	17.1	19.1
431 – 453 kg	14.1	4.3	10.0	7.4
≥ 454 kg	0.0	0.0	1.4	2.9
≥ 431 kg	14.1	4.3	11.4	10.3
Dressing Percent	65.04 ± 0.51	64.51 ± 0.45	64.31 ± 0.35	64.19 ± 0.38
Fat depth, cm	1.24 ± 0.05	1.30 ± 0.05	1.17 ± 0.05	1.22 ± 0.05
Ribeye area, cm^2	86.97 ± 2.58	86.71 ± 0.97	88.64 ± 1.48	88.58 ± 2.13
KPH, %	1.89 ± 0.07	1.93 ± 0.05	1.91 ± 0.07	1.91 ± 0.06
Calculated YG, units[d]	3.01 ± 0.13	3.05 ± 0.07	2.85 ± 0.04	2.92 ± 0.09
Marbling, units[e]	412.8 ± 15.0	402.6 ± 3.5	405.2 ± 14.4	417.5 ± 11.8
Quality Grade Category[b]				
≥ Avg. Choice	7.1	2.9	7.5	4.5
≥ Low Choice	57.2	50.7	47.7	48.5
Select	35.7	43.5	47.8	48.5
Standard	7.1	5.8	4.5	3.0
Yield Grade Category[b]				
Yield Grade 1 & 2	47.1	42.9	55.9	48.5
Yield Grade 3	40.0	40.0	32.4	37.9
Yield Grade 4 & 5	11.4	15.7	11.8	13.6

[a] Raw pen mean ± standard error of the mean unless stated otherwise.
[b] Percentage of individual carcasses.
[c] Ribeye area per cwt hot carcass weight.
[d] Yield grade calculated from carcass measurements.
[e] Marbling score units; $Slight^{00}$ = 300, $Small^{00}$ = 400; $Modest^{00}$ = 500.

Appendix H

Nitrogen retention was calculated using equations published in Figure 3-1 of NRC (2000).

Nitrogen retained (g) = (Protein retained (kg) ÷ 6.25) x 1000; where 6.25 is a function of the average protein containing 16% N.

Protein retained (kg) = EBPF, kg – EBPI, kg; where EBPF equals empty body protein at slaughter and EBPI equals empty body protein at treatment initiation.

$EBPF = 0.235 \times EBW_{slaughter} - 0.00013 \times (EBW_{slaughter})^2 - 2.418$

$EBPI = 0.235 \times EBW_{initial} - 0.00013 \times (EBW_{initial})^2 - 2.418$

EBW = 0.891 x SBW, where SBW equals shrunk body weight (kg).

SBW = Scale weight (kg) – 4% shrink.