Influence of yeast cell wall supplementation during the finishing phase on feedlot steer
performance, carcass characteristics and post-mortem tenderness

by

Samantha Aragon, B.S.

A Thesis

In

Animal Science

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

Master of Sciences

Approved

Bradley Johnson, Ph.D.
Chair of Committee

Sara Trojan, Ph.D.

Michael Ballou, Ph.D.

Dominick Casadonte
Interim Dean of the Graduate School

August, 2013

Copyright 2013, Samantha Aragon

ACKNOWLEDGMENTS

I owe my gratitude to numerous people in helping along my journey thus far. First and foremost I would like to thank my family for offering their continuous support in my endeavors. Thank you to my advisor, Dr. Johnson, and my committee for offering up wisdom, advice and opportunity. Furthermore, I could not have achieved this without the help of my fellow graduate students and I greatly appreciate all they have done for me. I would also like to thank Kirk Robinson and Ric Rocha for their constant patience in answering any and all questions that arose throughout my project. Lastly, I want to acknowledge every teacher and professor I have had throughout my educational career. Each of these influential people offered up knowledge and valuable lessons that influence who I am today.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS.....	ii
ABSTRACT.....	v
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
I. LITERATURE REVIEW.....	1
Introduction.....	1
Conventional Production.....	4
<i>β-Adrenergic-Agonists.....</i>	<i>4</i>
<i>Steroidal Implants.....</i>	<i>6</i>
<i>Ionophores and In-feed Antibiotics.....</i>	<i>9</i>
Natural Production Options.....	12
<i>Organic and Grass-fed Beef Production.....</i>	<i>12</i>
<i>Direct-fed Microbials.....</i>	<i>15</i>
<i>Yeast Supplementation.....</i>	<i>17</i>
<i>Vitamin D₂ and D₃.....</i>	<i>20</i>
Conclusions.....	21
Literature Cited.....	22
II. INFLUENCE OF YEAST CELL WALL SUPPLEMENTATION DURING THE FINISHING PHASE ON FEEDLOT STEER PERFORMANCE, CARCASS CHARACTERISTICS AND POST-MORTEM TENDERNESS	32
Abstract.....	32

Introduction.....	33
Materials and Methods.....	34
<i>Live Performance and Carcass Characteristics.....</i>	<i>34</i>
<i>Cattle.....</i>	<i>34</i>
<i>Experimental Design, Treatment and Pen Assignment.....</i>	<i>35</i>
<i>Management and Treatment Application.....</i>	<i>35</i>
Post-Mortem Tenderness.....	38
<i>Steak Handling.....</i>	<i>38</i>
<i>Warner-Bratzler Shear Force.....</i>	<i>38</i>
Statistical Analysis.....	39
Results.....	40
<i>Live Performance and Carcass Characteristics.....</i>	<i>40</i>
<i>Post-Mortem Tenderness.....</i>	<i>40</i>
Discussion.....	41
Conclusions.....	44
Tables and Figures.....	45
Literature Cited.....	55

ABSTRACT

Objectives were to evaluate benefits of yeast cell wall (**YCW**) supplementation on performance, carcass traits and tenderness of steers finished with zilpaterol hydrochloride (**ZH**). A randomized complete block design was used. British X Continental steers ($n = 72$; initial BW = 305 ± 13 kg) were blocked by BW and allotted randomly to 24 pens (8 pens/treatment; 3 pens/block; 3 steers/pen). Treatments were: 1) control (**CON**); 2) YCW containing 100,000 IU vitamin D₂/g ($5.0 \text{ g} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$) (**Y-D**); 3) YCW C ($5.0 \text{ g} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$) (**Y-C**). Steers were supplemented with respective treatments for 55 d, of which ZH was fed d 30-49. Cattle were weighed at d 0, 21, and 55. Carcass data was collected at the plant, and strip loins were obtained. Strips were cut into steaks and assigned to one of four aging periods (7, 14, 21 or 28 d). Tenderness was examined using Warner-Bratzler shear force (**WBSF**). Shrink performance showed no differences. Carcass adjusted average daily gain (**ADG**) from d 21-55 was 0.29 kg greater for Y-D and 0.35 kg greater for Y-C when compared to CON ($P = 0.04$ and 0.01 , respectively). Additionally, YCW increased G:F from d 21-55 with a 20.77% improvement for Y-D and 28.46% for Y-C over CON ($P = 0.06$ and 0.01 , respectively). Carcass data revealed no differences, yet there was a trend for a 6 kg increase in HCW by both Y-D and Y-C compared to CON ($P = 0.16$ and 0.12). The treatment $\times$ aging interaction with the WBSF data was not significant ($P = 0.20$) and no differences were found in cooking loss ($P = 0.88$). Treatment Y-C displayed WBSF values 0.30 kg higher than CON and 0.29 kg greater than Y-D ($P = 0.0062$ and 0.0075). Within the 7 d aging period, Y-C steaks were 0.62 kg ($P = 0.005$) and 0.54 kg ($P = 0.014$) less tender than CON or Y-D, respectively. For 14 d steaks, Y-C WBSF values were 0.58 kg greater than CON ($P = 0.008$). No

differences were found in the 21 or 28 d aging periods. The frequency distribution of WBSF values consistently displayed a trend for tougher Y-C steaks within each aging period. These data indicate yeast cell wall supplementation could increase performance of finishing steers while vitamin D₂ supplementation at the current dosage yielded no beneficial effects on tenderness.

LIST OF TABLES

2.1	90% Concentrate Diet Composition.....	44
2.2	90% Concentrate Diet Nutrient Analysis.....	44
2.3	Shrunk Live Performance.....	45
2.4	Carcass Adjusted Live Performance.....	46
2.5	Carcass Characteristics.....	47
2.6	Warner-Bratzler Shear Force- Main Treatment Effect.....	48
2.7	Warner-Bratzler Shear Force- By Aging Period.....	49

LIST OF FIGURES

2.1	Warner-Bratzler Shear Force Distribution- Aged 7 Days.....	50
2.2	Warner-Bratzler Shear Force Distribution- Aged 14 Days.....	51
2.3	Warner-Bratzler Shear Force Distribution- Aged 21 Days.....	52
2.4	Warner-Bratzler Shear Force Distribution- Aged 28 Days.....	53

CHAPTER I LITERATURE REVIEW

Introduction

As the majority of society has become distanced from agricultural production through the years, consumer concern over modern practices has risen. Adding to this apprehension are technological advances aimed to improve the economics of food production. These informational breakthroughs over the last century have resulted in a more commercialized agriculture industry employing less than 2% of the U.S. population and have lead to a society that is very disconnected from food production (Field, 2007). Specifically, animal protein production has made great strides since the cattle drives of the 1800's. Unfortunately, some consumers feel that in an effort to improve production, important factors may have been overlooked.

Early on in U.S. history, every family operated a small farm that provided the necessities for living. As the population grew and industrialization took place, the agriculture industry transformed as well. There were urban populations without the capabilities of producing their own food. Farmers began to specialize in only a few areas of production and created businesses. The beef industry is very broad encompassing areas of breeding, feeding and marketing. Expecting producers to be versed in all divisions of the industry and maintain efficiency on the large scale that the population demanded was unrealistic. In response to this, the beef industry became segmented to include seedstock breeders, cow-calf producers, stockers, feeders, packers, purveyors and retailers (Field, 2007). This format allowed each segment to focus on efficiency within a specific phase

of production. However, much of the concern voiced over beef industry practices centers around the feedlot sector.

The grain fed cattle industry emerged after World War II and continued to grow for the next 20 years due to an oversupply of grain as a cheap feed resource (Field, 2007). Efficiency of production became an important factor in the business, as cattle feeders in areas far from commodity production showed it is possible to import both grain and feeder cattle and still turn a profit (Field, 2007). As feeding operations increased in size, corporate ownership of feedlots became more common.

These large feedlots are generally dirt lot housing in comparably small pens to that of the pastures the calves may have been raised on for the first part of their lives. Feed is delivered in concrete bunks along one side of the pen, and pen capacity is determined by the bunk space provided per head. These facilities are often referred to as confinement operations by the public. Due to vehicle traffic and cattle movement in these dirt lots, a high dust pollution and unpleasant odor is often emitted. Consumers view these concentrated populations of cattle in a negative light, especially in contrast with other segments of production, such as the stereotypical large green pastures of a commercial cow-calf operation. When making these criticisms, the general population that has become disassociated with livestock production does not consider the decline in efficiency that would result in regressing to a pasture fed cattle industry. Feedyard facilities are not the only aspect of the industry that has evolved to meet the retail demand of beef.

With this emphasis on efficiency, financial support for research in improving cattle performance in the feedyard surfaced. Growth and feeding technologies have emerged from this research that have revolutionized cattle feeding practices. In the early 1950's, the first hormone based growth promotant was discovered to increase average daily gain (**ADG**) and feed efficiency (Raun and Preston, 2002). Not long after, in the mid 1970's ionophore feed additives were approved for use in ruminants (Russell and Strobel, 1989). These antibiotic based supplements alter ruminal fermentation in order to improve energy metabolism and digestive health (Russell and Strobel, 1989). Another development in cattle feeding technology was the approval of β -adrenergic-agonist (**β -AA**) agents. Ractopamine hydrochloride was approved for use in beef cattle in the US in 2003 followed by the approval of zilpaterol hydrochloride in 2006 (Avendaño-Reyes et al., 2006). β -adrenergic-agonists repartition nutrients toward lean tissue deposition to increase ADG, feed efficiency, and carcass yield (Anderson et al., 2005). With such industry altering developments in the last century, the feedlot sector has become increasingly corporate and commercialized in order to meet the public's demand for quality beef.

The use of these technologies is now necessary to maintain competitive cattle performance and profitability in the feedlot business. However, consumers have understandable concerns not only with feedlot housing conditions, but with food production practices that rely on antibiotic and hormone based growth promotants. There has recently been a call from society for more naturally based production practices in an effort to increase the animals' perceived quality of life as well as food quality and safety.

There is much debate upon what method of production is most ethical. Natural methods generally go back to historical practices with cattle finished on pasture and remove any additives. Natural or organic producers target a niche market of consumers willing to pay extra at the grocery store, while the conventional cattle feeder supplies animal protein to the majority of society that has yet to act on those concerns or is not willing to pay the premium at the grocery store. This review will examine both conventional feedlot production and natural cattle feeding options in an effort to better understand the ideal future of the beef industry that will satisfy both producers and consumers.

Conventional Production

β -Adrenergic-Agonists

Pharmaceutical companies began investigating β -AA in the 1970's and patents were issued in the 1980's (Anderson et al., 2005). These are part of the phenothanolamines class of compounds and are used as a feed ingredient as they are orally active (Anderson et al., 2005). β -adrenergic-agonists alter metabolic signals in muscle and fat cells to redirect nutrients toward increasing lean tissue accretion and lypolysis and decreasing lypogenesis (Anderson et al., 2005). These signals are generated by β -AA binding to β -adrenergic receptors and resulted in more efficient utilization of nutrients illustrated by increase in carcass muscling and dressing percentage (Anderson et al., 2005). Ractopamine hydrochloride (**RH**) and zilpaterol hydrochloride (**ZH**) are the two β -AA approved for use in beef cattle in the United States (Scramlin et al., 2010) . Each compound yields slightly different results.

Scramlin et al. (2010) conducted a study comparing the performance, carcass traits and longissimus tenderness of finishing steers. Both compounds increased final body weight (**BW**), ADG, feed efficiency, and hot carcass weight (**HCW**) when compared to control (Scramlin et al., 2010). However, between the two compounds, RH showed a greater increase in ADG, dry matter intake (**DMI**), and final BW while ZH increased HCW and dressing percentage relative to RH (Scramlin et al., 2010). Of particular interest are the differences in magnitude of response between the two compounds. Scramlin et al. (2010) reported a 5.3 kg increase in HCW in cattle fed RH and a 12.8 kg increase in HCW of cattle fed ZH. Furthermore, final BW were not increased at the same magnitude and this response is explained by the repartitioning effect of ZH on fat metabolism of noncarcass components (Scramlin et al., 2010). Furthermore, ZH decreased fat deposition, increased rib eye area (REA) and improved yield grade compared to controls (Scramlin et al., 2010). Unfortunately, steaks from those steers fed ZH were less tender compared to both the control and RH steers (Scramlin et al., 2010).

Avendaño-Reyes et al. (2006) found similar outcomes in a comparable study involving RH and ZH supplementation of crossbred feedlot steers. Both β -AA improved ADG, feed efficiency, HCW and carcass yeild, however RH decreased intake compared to control and ZH fed steers (Avendaño-Reyes et al., 2006). Steers fed ZH displayed larger REA versus control and RH treatments, however steaks from both ZH and RH supplemented groups resulted in greater shear force values (Avendaño-Reyes et al., 2006).

In a study focusing heavily on meat quality, Strydom et al. (2009) examined the effects of RH, ZH and clenbuterol (**CL**), a β -AA no longer approved for use in commercial beef production in the US. Along with the expected benefits in live performance, all β -AA affected tenderness negatively; however the greatest effect came from CL followed by ZH and then RH (Strydom et al., 2009). These differences in tenderness were explained at the biochemical level. Strydom et al. (2009) observed higher calpastatin activity in all β -AA treatments compared to control. It is clear that there are downsides to the use of β -AA in beef cattle production related to meat quality. Still, Avendaño-Reyes et al. (2006) reported meat tenderness of cattle fed either approved β -AA treatment was described as intermediate (Avendaño-Reyes et al., 2006). With the profitable increase in efficiency resulting from β -AA supplementation, some cattle feeders have decided that the benefits outweigh the disadvantages in product quality.

Steroidal Implants

In 1954, the first hormone based growth promotant, diethylstilbestrol (**DES**), was approved for oral administration in cattle (Raun and Preston, 2002). Diethylstilbestrol improved fed steer ADG and feed efficiency, and was later approved as a hormonal implant for cattle in 1957 (Raun and Preston, 2002). Although approval of compound was later revoked, this discovery paved the way for the development of other anabolic implants. In an overview of beef cattle implants, Zobell et al. (2000) explains that early on, the only implants available were estrogen based and improved feed efficiency 5-10 % and ADG 5-15 %. In 1987, trenbolone acetate (**TBA**), an androgenic agent, was approved for use as an implant in beef cattle and when combined with existing estrogenic agents,

further improved feed efficiency 2-3 % and added 3-5 % to ADG while also increasing lean tissue deposition (Zobell et al., 2000). Immediately following implantation, hormone is quickly released (Zobell et al., 2000). This level decreases after a few days but will still remain above the effective threshold for the payout window, which varies depending on the implant design (Zobell et al., 2000). Albin (1990) indicated that the anabolic response period to implants last 70-120 days, therefore longer feeding periods often require re-implantation to take full advantage of the added growth and efficiency these compounds promote.

Furthermore, Zobell et al. (2000) explains that yearling cattle receiving high energy diets, such as rations that would be found in a feedyard, exhibited the greatest response to these implants. The mechanism of action of estrogenic and androgenic agents differ. Estrogen based implants increase the amount of circulating somatotropin and insulin-like growth factor-I (**IGF-I**) while TBA implants also increase IGF-I; however, rather than stimulating somatotropin production, estrogen implants decrease normal muscle tissue loss (Zobell et al., 2000). The degree of this response is dependent upon nutrients available and the dose associated with the implant (Zobell et al., 2000).

In an overview of implant use in beef cattle production, Montgomery, Dew and Brown (2001) explained that these hormone based growth promotants are known to increase performance, lean tissue accretion, carcass weight and rib eye area. Foutz et al. (1997) examined the effects of estrogenic, TBA and estrogen/TBA combination implants on feedlot steer performance. An estrogen/TBA combination increased ADG and feed efficiency and steers implanted with TBA alone yielded larger longissimus areas (Foutz

et al., 1997). All implants increase lean yield when compared to control however the largest increases occurred in steers receiving TBA or estrogen/TBA combination implants (Foutz et al., 1997).

Additionally, Parr et al. (2011) investigated the use of TBA/estrodinol implants in conjunction with feeding ZH. No interaction was found between implant and ZH supplementation (Parr et al., 2011). Implants increased performance compared to that of control illustrating that implant mechanism of action is separate from that of β -AA (Parr et al., 2011). Parr et al. (2011) also reported an extended pay out period and increased performance associated with higher doses of TBA and estradiol.

Montgomery, Dew and Brown (2001) stated with increased use of hormonal implants, concern has risen over the influence of implants on meat quality. Anabolic implant use has resulted in decreased quality grade and a variable increase in skeletal maturity (Montgomery, Dew & Brown, 2001). Foutz et al. (1997) reported steers implanted with TBA displayed a tendency for lower marbling scores and yield grades. Furthermore, steers implanted with an estrogen/TBA combination exhibited lower quality grades (Foutz et al., 1997). Steaks from all implanted treatments increased shear force values (Foutz et al., 1997). Duckett et al. (1999) examined the effects of implants on intramuscular lipid content and found increased percentages of saturated fatty acids and reduced percentages of monounsaturated fatty acid in the longissimus of implanted steers. However, it is also stated that when evaluated relative to the increase in longissimus area, these differences in fatty acid profiles are insignificant (Duckett et al., 1999).

Ionophores and In-feed Antibiotics

Ionophores are described as highly lipophilic substances that are toxic to many bacteria, protozoa and fungi and because of this property, are classified as antibiotics (Russell and Strobel, 1989). Solomons (1978) looked into the sub therapeutic use of antibiotics in livestock and identified three main purposes of their use: improved gain and efficiency, disease prevention, and disease therapy. The mechanism of action of ionophores in the rumen is due to target microorganism sensitivity, ion selectivity of the ionophore, concentration gradient of the ions to be translocated, and increase ion flux through the cell membrane (Russell and Strobel, 1989).

Russell and Strobel (1989) explained the influence of ionophores on ruminal fermentation. Supplementing with ionophores decrease methane production and increase propionate production, thus reducing energy loss and amplifying feed energy available (Russell and Strobel, 1989). Furthermore, ionophores reduce ammonia production and nitrogen lost through urine causing a “protein-sparing” effect (Russell and Strobel, 1989). Guan et al. (2006) found similar effects and reported a decrease in ruminal fluid ammonia concentration and acetate:propionate ratio. Additionally, a four week decrease in both methane emissions and ruminal protozoa population was observed, indicating the methane reduction correlated to the alteration of microbial population (Guan et al., 2006). Specific to feedlot production, high concentrate diets can often result in decreased ruminal pH and increased incidence in acidosis. Feeding ionophores can stabilize ruminal pH and result in a healthier microbial population (Russell and Strobel, 1989). Through

these modes of action, ionophores are known to increase live performance and feed efficiency.

Raun et al. (1976) supplemented various levels of monensin and found similar or increased ADG while decreasing intake compared to the control cattle. As a result, feed efficiency was improved between 10-17 percent (Raun and Preston, 2002). In a similar study feeding the ionophore tetronasin to growing and finishing beef cattle, Bartle, Preston and Bailie (1988) reported no changes in ADG with decreased intake, thus increasing feed efficiency about 10 percent at the optimum dose. Another feed additive commonly used in conjunction with ionophores are chronically in-feed antibiotics.

These in-feed antibiotics are known to increase feedlot performance and reduce incidence of liver abscesses (Albin, 1990). Albin (1990) explains that liver abscesses are a problem associated with high concentrate diets or irregular management causing erratic changes in dry matter intake. In severe cases, liver abscesses have greatly reduced ADG (Brown et al., 1975). One fed antibiotic used to combat these abscesses is tylosin. Brown et al. (1975) reported an increase in ADG and feed efficiency due to tylosin supplementation. Furthermore, tylosin effectively reduced incidence of liver condemnation by 37.6 percent (Brown et al., 1975). Because in-feed antibiotics are often paired with ionophores, much of the research involving tylosin also included monensin supplementation.

Pendlum, Boling and Bradley (1978) conducted a study using varying levels of monensin with and without tylosin. Tylosin supplementation decreased DMI, however feed-to-gain (**F:G**) ratios were increased, HCW were lower and REA were smaller

(Pendlum et al., 1978). Still, tylosin also reduced incidence of liver abscesses (Pendlum et al., 1978). Meyer et al. (2009) observed decreased DMI and improved feed efficiency and ADG as a result of monensin and tylosin supplementation. Galyean, Malcolm and Duff (1992) reported similar findings with reduced DMI in steers fed both monensin and tylosin. Additional effects have been observed when supplementing antibiotics and ionophores with β -AA.

Montgomery et al. (2009) conducted a study examining the effects steers fed ZH with or without monensin and tylosin. While ZH decreased marbling, the effects on quality grade were moderated with monensin and tylosin supplementation (Montgomery et al., 2009). Similarly, ZH decreased calculated yield grade, but the yield grade of steers not fed monensin or tylosin were even lower (Montgomery et al., 2009). Furthermore, Hilton et al. (2009) used steaks from steers fed ZH with and without monensin and tylosin for a consumer sensory panel and reported that the withdrawal of monensin and tylosin decreased consumer juiciness scores. These findings indicate that ionophore and antibiotic supplementation may mediate the effects of ZH on carcass quality.

While the advantages of ionophores and in-feed antibiotics are clear to producers, the classification as an antibiotic causes the public to perceive these products with a negative connotation and connect them with possible antimicrobial resistance. Antibiotic resistance is a common concern of both producers and consumers when discussing in-feed antibiotics. This resistance can stem from three different mechanisms: synthesis of enzymes that degrade the antibiotic, cellular target alteration and change in cellular permeability (Russell and Strobel, 1989). Resistance is often caused by transfer of genes

encoding resistance factors from one strain or species to another (Russell and Strobel, 1989). In an examination of compiled studies, Solomons (1978) determined that chickens fed low levels of chronic antibiotics had a greater number of resistant *Salmonella* and *E. coli* bacteria residing in their intestinal tracts. Dealy and Moeller (1977) implicated that calves treated with antibiotics had greater levels of intestinal *E. coli* resistant to that antibiotic. While this data may pose cause for concern, Russell and Strobel (1989) postulate that rotation of ionophore feeding does not only improve animal performance but may be the key to preventing bacterial resistance while still taking advantage of this increase in efficiency.

Natural Production Options

Organic and Grass-fed Beef Production

While some consumers may claim to prefer organic products, few realize the intensity of regulations which livestock producers must follow to receive certification. The USDA's National Organic Program (2013) requires an in depth list of conditions be met including pasture and housing conditions, ration ingredients, feed additives, treatment of illness and record keeping. Cattle destined for organic beef production must be raised under these specified conditions starting during the third trimester of gestation through the packing plant (USDA, 2013). No drugs or synthetic parasiticides may be administered at any time except vaccinations, however conventional treatment practices must be used for ill animals when organic methods fail and the treated animal must be removed from further organic production (USDA, 2013). Rations must be comprised of completely organic feedstuffs and 30 percent of the animal's roughage dry matter intake

is to be obtained from organic pasture grazing, except for the finishing period defined as the last 120 days before slaughter (USDA, 2013). No hormone or drug based growth promontants may be used and ionophores and antibiotics are to be excluded from the diets (USDA, 2013). Furthermore, records are to be kept of all purchased animals, feedstuffs grown on the farm and purchased, treatments administered, and rations formulated to meet but not exceed the animal's requirements (USDA, 2013). While the concept of organic production may be appealing to producers, the degree of micromanagement needed to produce organic beef coupled with the elimination of growth technologies available in conventional systems causes producers to question the profitability of this option.

Woodward and Fernández (1999) compared conventional and organic finishing systems in beef cattle and reported larger HCW and REA from conventionally fed steers. Additionally, the organic steers yielded greater backfat and increased marbling compared to conventional steers (Woodward and Fernandez, 1999). Without growth promoting technologies, organic producers must sacrifice the added efficiency gained with conventional systems. Boland (2002) conducted an economical review of organic beef production and found that while production costs may be higher, a producer may still decide to participate in this niche marketing option if sufficient economic incentives exist. Unfortunately, this higher premium at the packer level also translates into higher retail prices for consumers. Napolitano et al. (2010) examined consumer preference of organic beef and willingness to pay the extra premium. Perceived preference of organic beef based on information given was higher than actual taste preference while perceived

and actual liking of conventionally produced beef was equal (Napolitano et al., 2010). Furthermore, consumers claimed to be willing to pay the extra premium for organic beef based on information given concerning production practices (Napolitano et al., 2010). While the concept of organic production seems appealing to consumers causing a willingness to purchase the product at a higher price, the actual liking based on taste did not meet up to expectations. Because organic production entails such heavy regulations to obtain certification, some producers have targeted an alternative market with grass-fed beef. The term “grass-fed” refers to cattle that have been finished on pasture rather than high concentrate grain diets in a feedlot and often excludes the use of added hormones and antibiotics (McCluskey et al., 2005).

In an extensive study with the objective of establishing nutrient composition of grass-fed beef compared to conventionally raised grain-fed cattle, Leheska et al. (2008) determined that while grass-fed beef yielded less total fat content, both grass and grain-fed were considered lean. Grass-fed beef did display health advantages to the consumer as it contained higher content of conjugated linoleic acid (**CLA**), higher levels of saturated fatty acids (**SFA**) and lower levels of monounsaturated fatty acids (**MUFA**) were also found when compared to grain-fed beef (Leheska et al., 2008). Leheska et al. (2008) further explained this difference in fatty acid profiles was due to greater concentration of stearic acid in grass-fed beef and of oleic acid in grain-fed. Some research does disagree with these findings, as French et al. (2000) reported higher concentrations of polyunsaturated fatty acids (**PUFA**) were found in the intramuscular fat of grass-fed steers. Additionally, decreasing the level of concentrate in the diet and

increasing grass intake resulted in a linear increase in PUFA:SFA ratio (French et al., 2000). One aspect of grass-fed production possibly more relevant to the producer than nutritional content of the product, is the significant change in production systems and the cost associated with those transformations.

As with organic beef, producers must receive a higher premium for grass-fed beef in order to maintain profitability. Umberger et al. (2002) conducted a consumer taste panel comparing domestic grain-fed beef and Argentine grass-fed beef. Consumers were willing to pay an average of a 30.6% premium for concentrate finished beef based on taste preference (Umberger et al., 2002). Sitz et al. (2005) reported similar findings when comparing domestic grain-fed beef and Australian grass-fed beef in a consumer taste panel. Domestic steaks received higher scores for flavor, juiciness, tenderness and overall acceptability (Sitz et al., 2005). Furthermore, Leheska et al. (2008) stated that steaks from grass-finished cattle exhibited fat more yellow in color, which may cause consumers to view those steaks more negatively based on appearance in the retail case. This information reveals that producers must market grass-fed beef as a natural production system to achieve an added premium rather than highlighting these taste differences.

Direct-fed Microbials

Direct-fed microbials (**DFM**) and probiotics are terms sometimes used interchangeably in the livestock industry. While probiotic is a broader term defined as a live microbial feed supplement with beneficial affects to the host by altering the intestinal microbial population, the U.S. FDA has classified the livestock feed additive sector of probiotics as direct-fed microbials (Krehbiel et al., 2003). Salminen, Isolauri and

Salminen (1996) explain the mode of action behind DFM is based upon gut microflora modification, adhering to the intestinal mucosa with the ability to prevent pathogen adherence or activation, altering of dietary proteins by gut microflora, modification of enzyme activity, and change in gut mucosal permeability. Through this mode of action, it has been postulated that DMF supplementation can improve health and performance of feedlot cattle (Krehbiel et al., 2003) and reduce shedding of pathogenic bacteria such as *E. coli* O157:H7 (Elam et al., 2003).

In an overview of DFM, Krehbiel et al. (2003) explained that performance responses have varied, however an increase in feed efficiency has been reported as a result of DFM supplementation. Galyean et al. (2000) conducted a study feeding various forms of lactic acid producing bacteria and observed an increase in final BW, ADG and feed efficiency among all DFM treatment groups when compared to the control. In contrast, Elam et al. (2003) and Peterson et al. (2007) conducted two additional studies supplementing with *Lactobacillus acidophilus* (**LA**) strains reported no significant differences in live performance. However, studies examining DFM and reduction in pathogens shed by feedlot cattle reported more consistent findings. Peterson et al. (2007) indicated that steers treated with LA strain NP-51 were 15 to 35 percent less likely to shed *E. coli* O157:H7. In agreement, Elam et al. (2003) reported that supplementing LA strain NP-51 or a combination of NP-51 and NP-45 reduced fecal *E. coli* O157:H7 shedding and linked this response to an observed reduction in lamina propria thickness.

More recently, Bernhard et al. (2012) conducted a study supplementing finishing steers with LA and *Propionibacterium freudenrichii* (**PF**). Direct-fed microbial

supplementation increased feed efficiency and linear increases in LA concentration resulted in a linear decrease of *E. coli* O157:H7 fecal prevalence and concentration (Bernhard et al., 2012). Furthermore, Aragon et al. (2013) reported data from two similar studies, one large and one small pen, which supplemented feedlot steers with LA and PF. No differences in performance were observed, however significant decreases in fecal *E. coli* O157:H7 prevalence and concentration, lymph node *Salmonella* prevalence and concentration, and prevalence of fecal *E. coli* non-O157 types were documented (Aragon et al., 2013). While research concerning live performance response to DFM may be inconsistent, there is also great value in the pathogen reduction seen with LA supplementation. The use of DFM as a pre-harvest intervention to reduce incidence of carcass contamination could lead to a safer food supply.

Yeast Supplementation

Yeast feed supplements are thought to increase performance and animal health by acting as an immune modifier. *Saccharomyces cerevisiae* is a yeast culture that is evaluated for its effects on animal performance and immune function (Jurgens et al., 1997). In an in vitro study Newbold et al. (1996) reported that the mode of action of *Saccharomyces cerevisiae* in ruminants stem from their respiratory activity in the rumen. The yeast culture increased O₂ disappearance and stimulated both the total and cellulolytic bacteria populations (Newbold et al., 1996).

Because of the immune modification aspect of yeast feed additives, their application is often studied during times of stress. Cole et al. (1992) reported that yeast culture had beneficial effects on feeder calf morbidity and DMI, yet this effect is more

pronounced in stressed calves. Knowing the benefits of yeast supplementation during times of stress, it has been examined as a useful feed additive during the receiving period. However, there are times of stress during the finishing phase as well. Strydom et al. (2009) reported a significant decrease in DMI of cattle fed ZH compared to control cattle. Therefore, the application of immune modifiers, such as yeast products, during a time of metabolic stress is of interest.

Performance data from yeast supplementation trials can be conflicted. Mir and Mir (1994) found that yeast supplementation decreased feed efficiency and digestion with no differences in performance. Keyser et al. (2007) supplemented newly received beef heifers with a yeast culture upon arrival and supplemented in feed subsequently and reported a decrease in BRD morbidity due to the supplementation. However, this difference was only seen in calves that also received a metaphylactic treatment. The results that reported a decrease or no difference in performance likely stem from the greater pronunciation of beneficial effects seen in stressed calves. Cole et al. (1992) reported that feeder calves affected by infectious bovine rhinotracheitis virus (**IBRV**) maintained higher DMI and heavier BW when supplemented with a yeast culture. Eicher et al. (2006) indicated that yeast supplementation in newborn pigs increased BW and ADG. Additionally, Shen et al. (2009) found similar advantages in performance of nursery pigs and linked this effect to increased immune function. It is widely accepted that the advantages seen in performance are due to the increase in immune function initiated by yeast supplementation.

As an immune modifier, yeast products have been widely studied as supplement to animals with a compromised immune system. When fed to nursery pigs, Shen et al. (2009) found that yeast culture supplementation improved villus height, gut immune response and nutrient digestibility, suggesting that yeast culture may be an alternative to antibiotic growth promoters. Furthermore, calves supplemented with yeast culture displayed fewer sick days when infected with IBRV (Cole et al., 1992). Eicher et al. (2006) conducted a lipopolysaccharide (**LPS**) challenge on newborn pigs, and found that yeast supplementation increased immune function. Magalhães et al. (2007) observed improved survival rate in Holstein calves receiving a yeast supplement and led to an increase in income at the end of the study of \$48/ calf. Because fed yeast acts in the digestive tract, research has been conducted into the use of yeast products to beneficially modify the rumen environment.

Bloat in a feedyard is a result of an overconsumption of rapidly fermentable grains and the incidence of bloat reduces profitability through decreased animal performance and potentially increasing death loss (Cheng et al., 1998). Yeast supplementation offers an opportunity to reduce acidosis occurrences and lower risk of bloat in feedlot cattle. Moya et al. (2009) induced acidotic conditions in the rumen of Holstein heifers and found that yeast supplementation decreased the severity of the bloat. In ruminally fistulated Holstein cows, Harrison et al. (1988) revealed that yeast supplementation resulted in less variation of ammonia concentrations and increased cellulolytic bacteria concentrations which led to more stable ruminal fermentation. In Holstein calves fed a yeast culture, improved fecal cores and reduced incidence of fever

and diarrhea were reported (Magalhães et al., 2007). Additionally Beauchemin et al. (2003) reported that combining yeast with a DFM increased the digestion of corn in feedlot cattle. Collectively, this information suggests that yeast supplementation may increase grain digestibility while buffering the rumen environment to encourage a healthy microbial population.

Vitamin D₂ and D₃

In an effort to improve meat quality, it has been postulated that supplemental vitamin D can improve tenderness. There are two forms of supplemental vitamin D available: ergocalciferol (vitamin D₂) and cholecalciferol (vitamin D₃) (Houghton and Vieth, 2006). Of the two forms, vitamin D₃ has been the most extensively studied supplement in terms of altering tenderness. Swanek et al. (1999) explains the mechanism of vitamin D₃ supplementation as increasing blood calcium concentration, which in turn increases calpain activity. Montgomery et al. (2002) reported that vitamin D₃ increased tenderness in muscles with a tendency to be tough, but had no effect on cuts accepted as tender. When supplemented in conjunction with ZH, Hansen et al. (2012) found vitamin D₃ had no effect on Warner-Bratzler shear force (**WBSF**) but did shorten myofibrillar length, suggesting that differences in tenderness may not have been pronounced enough to be considered significant in the WBSF. Furthermore, in another study supplementing vitamin D₃ with ZH, some short term dosages of vitamin D₃ displayed beneficial effects on tenderness however electrical stimulation was more effective at reversing ZH induced toughness (Strydom et al., 2011).

Unfortunately, vitamin D₃ has been criticized as a potentially toxic feed supplement. Montgomery et al. (2002) explained that vitamin D₃ toxicity can result in prolonged hypercalcemia, decreased performance, and death. Additionally, the dosage of vitamin D₃ necessary to see the beneficial effects on tenderness are considered to be potentially toxic (Montgomery et al., 2002). However, vitamin D₂ may be a safer alternative.

Research disagrees whether the two forms of vitamin D can be used interchangeably. Houghton and Vieth (2006) explains that vitamin D₃ is a more potent form of the vitamin. This may account for the decreased incidence of toxicity seen with vitamin D₂ supplementation. Still, being that vitamin D₃ is a more concentrated form, it brings to question if they illicit the same response. Holick et al. (2008) has shown both forms to be equally effective in maintaining serum 25-hydroxyvitamin D levels. Conversely, Houghton and Vieth (2006) reported opposing results, stating that 25-hydroxyvitamin D levels were higher in people supplemented vitamin D₃ compared to its counterpart. Not enough research has been done comparing the effectiveness of the two forms of vitamin D in livestock, and more specifically in ruminant animals. Therefore, more data is needed in order to establish the value of vitamin D₂ in beef cattle production.

Conclusions

Although some consumers have a negative perception of the commercial beef industry, producers and researchers are aware of their concerns and are taking action to maintain or improve efficiency while satisfying societal preferences. Conventional products such as β -AA, steroidal implants, and antibiotic based feed supplements have

revolutionized the industry and allowed it to efficiently produce an economical source of lean protein. However, natural options such as DFM and yeast products could be an asset to producers targeting a niche market of consumers, being that they have shown to increase performance and stabilize the rumen microbial population. Grass-fed and organic beef may appeal to a group of consumers with more extreme opinions but considering most consumers have only moderate concerns, the solution may reside in substituting some conventional practices with natural options in order to maintain efficiency while addressing consumer requests.

Literature Cited

- Albin, R. C. 1990. Cattle Feeding: A Guide to Management. Tafton Printing, Inc., Amarillo, TX.
- Anderson, D. B., D. E. Moody, D. L. Hancock, W. Pond, and A. Bell. 2005. Beta adrenergic agonists. Marcel-Decker, Inc., New York, NY.
- Aragon, S. N., F. R. B. Ribeiro, L. M. Guillen, R. A McDonald, D. R. Ware, W. M. Kreikemeier, R. S. Swingle, M. M Brashears, G. H. Loneragan, and B. J. Johnson. 2013. The effects of Bovamine® Defend™ on prevalence and concentration of *Escherichia coli* O157:H7, non-O157 O types, and *Salmonella* in finishing steers. Texas Agrilife Research and Extension Center. Pub No. AREC 2013-24:122.
- Avendaño-Reyes, L., V. Torres-Rodríguez, F. J. Meraz-Murillo, C. Pérez-Linares, R. Figueroa-Saavedra, and P. H. Robinson. 2006. Effects of two β -adrenergic agonists on finishing performance, carcass characteristics, and meat quality of feedlot steers. J. Anim. Sci. 84: 3259-3265.

- Bartle, S., R. Preston, and J. Bailie. 1998. Dose-response relationship of the ionophore tetrinasin in growing-finishing cattle. *J. Anim. Sci.* 66: 1502-1507.
- Beauchemin, K. A., W. Z. Yang, D. P. Morgavi, G. R. Ghorgani, W. Kautz and J. A. Z. Leede. 2003. Effects of bacterial direct-fed microbials and yeast on site and extent of digestion, blood chemistry, and subclinical ruminal acidosis in feedlot cattle. *J. Anim. Sci.* 81: 1628-1640.
- Bernhard, B. C., M. A. Calle, G. H. Loneragan, M. M. Brashears, M. D. Edmonds, E. G. Johnson, D. R. Ware, W. M. Kreikemeier, and C. R. Krehbiel. 2012. Effects of Bovamine® supplementation on the prevalence and concentration of *Escherichia coli* O157:H7, non-O157 O types, and performance of finishing steers. Texas Agrilife Research and Extension Center. Pub. No. AREC 2012-26: 122.
- Boland, M., and T. Shroeder. 2002. Marginal value of quality attributes for natural and organic beef. *Journal of Agricultural and Applied Economics.* 34: 39-50.
- Brown, H., R. F. Bing, H. P. Grueter, J. W. McAskill, C. O. Cooley and R. P. Rathmachee. 1975. Tylosin and chlortetracycline for the prevention of liver abscesses, improved weight gains and feed efficiency in feedlot cattle. *J. Anim. Sci.* 40: 207-213.
- Cheng, K. J., T. A. McAllister, J. D. Popp, A. N. Hristov, Z. Mir and H. T. Shin. 1998. A review of bloat in feedlot cattle. *J. Anim. Sci.* 76: 299-308.
- Cole, N., C. Purdy, and D. Hutcheson. 1992. Influence of yeast culture on feeder calves and lambs. *J. Anim. Sci.* 70: 1682-1690.

- Dealy, J., and M. Moeller. 1977. Influence of bambermycins on *Salmonella* infection and antibiotic resistance in calves. J. Anim. Sci. 44: 734-738.
- Duckett, S., D. Wagner, F. Owens, H. Dolezal, and D. Gill. 1999. Effect of anabolic implants on beef intramuscular lipid content. J. Anim. Sci. 77: 1100-1104.
- Eicher, S., C. McKee, J. Carroll, and E. Pajor. 2006. Supplemental vitamin C and yeast cell wall β -glucan as growth enhancers in newborn pigs and as immune modulators after an endotoxin challenge after weaning. J. Anim. Sci. 84: 2352-2360.
- Elam, N. A., J. F. Gleghorn, J. D. Rivera, M. L. Galyean, P. J. Defoor, M. M. Brashears and S. M. Younts-Dahl. 2003. Effects of live cultures of *Lactobacillus acidophilus* (strains NP45 and NP51) and *Propionibacterium freudenreichii* on performance, carcass, and intestinal characteristics, and *Escherichia coli* strain O157 shedding of finishing beef steers. J. Anim. Sci. 81: 2686-2698.
- Field, T. G. 2007. Beef Production and Management Decisions. 5th ed. Pearson Prentice Hall, Upper Saddle River, NJ.
- Foutz, C. P., H. G. Dolezal, T. L. Gardner, D. R. Gill, J. L. Hensley and J. B. Morgan. 1997. Anabolic implant effects on steer performance, carcass traits, subprimal yields, and longissimus muscle properties. J. Anim. Sci. 75: 1256-1265.
- French, P., C. Stanton, F. Lawless, E. G. O'Riordan, F. J. Momahan, P. J. Caffrey, and A. P. Maloney. 2000. Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass, grass silage, or concentrate based diets. J. Anim. Sci. 78: 2849-2855.

- Galyean, M., K. Malcolm, and G. Duff. 1992. Performance of feedlot steers fed diets containing laidlomycin propionate or monensin plus tylosin, and effects of laidlomycin propionate concentration on intake patterns and ruminal fermentation of beef steers during adaptation to a high-concentrate diet. *J. Anim. Sci.* 70: 2950-2958.
- Galyean, M., G. Nunnery, P. Defoor, G. Salyer, and C. Parsons. 2000. Effects of live cultures of *Lactobacillus acidophilus* (Strains 45 and 51) and *Propionibacterium freudenreichii* PF-24 on performance and carcass characteristics of finishing beef steers. Burnett Center Progress Report.
- Guan, H., K. Wittenberg, K. Ominski, and D. Krause. 2006. Efficacy of ionophores in cattle diets for mitigation of enteric methane. *J. Anim. Sci.* 84: 1896-1906.
- Hansen, S., L. Frylinck, and P. E. Strydom. 2012. The effect of vitamin D₃ supplementation on texture and oxidative stability of beef loins from steers treated with zilpaterol hydrochloride. *J. Meat Sci.* 90: 145-151.
- Harrison, G., R. Hemken, K. Dawson, R. Harmon, and K. Barker. 1988. Influence of addition of yeast culture supplementation to diets of lactating cows on ruminal fermentation and microbial populations. *J. Dairy Sci.* 71: 2967-2975.

- Hilton, G., J. L. Montgomery, C. R. Krehbiel, D. A. Yates, J. P. Hutcheson, W. T. Nichols, M. N. Streeter, J. R. Blanton Jr. and M. F. Miller. 2009. Effects of feeding zilpaterol hydrochloride with and without monensin and tylosin on carcass cutability and meat palatability of beef steers. *J. Anim. Sci.* 87: 1394-1406.
- Holick, M. F., R. M. Biancuzzo, T. C. Chen, E. K. Klein, A. Young, D. Bibuld, R. Reitz, W. Salameh, A. Ameri and A. D. Tannenbaum. 2008. Vitamin D₂ is as effective as vitamin D₃ in maintaining circulating concentrations of 25-hydroxyvitamin D. *J. Clinical Endocrinology & Metabolism.* 93: 677-681.
- Houghton, L. A., and R. Veith. 2006. The case against ergocalciferol (vitamin D₂) as a vitamin supplement. *Amer. J. Clinical Nutrition.* 84: 694-697.
- Jurgens, M., R. Rikabi, and D. Zimmerman. 1997. The effect of dietary active dry yeast supplement on performance of sows during gestation-lactation and their pigs. *J. Anim. Sci.* 75: 593-597.
- Keyser, S., J. McMeniman, D. Smith, J. MacDonald, and M. Galyean. 2007. Effects of *Saccharomyces cerevisiae* subspecies bouldarii CNCM I-1079 on feed intake by healthy beef cattle treated with florfenicol and on health and performance of newly received beef heifers. *J. Anim. Sci.* 85: 1264-1273.
- Krehbiel, C., S. Rust, G. Zhang, and S. Gililand. 2003. Bacterial direct-fed microbials in ruminant diets: Performance response and mode of action. *J. Anim. Sci.* 81: E120-E132.

- Leheska, J. M., L. D. Thompson, J. C. Howe, E. Hentges, J. Boyce, J. C. Brooks, B. Shriver, L. Hoover and M. F. Miller. 2008. Effects of conventional and grass-feeding systems on the nutrient composition of beef. *J. Anim. Sci.* 86: 3575-3585.
- Magalhães, V. J. A., F. Susca, F. S. Lima, A. F. Branco, I. Yoon and J. E. P. Santos. 2008. Effect of feeding yeast culture on performance, health and immunocompetence of dairy calves. *J. Dairy Sci.* 91: 1497-1509.
- McClusky, J. J., T. I. Wahl, Q. Li, and P. R Wandschneider. 2005. US grass-fed beef: Marketing health benefits. *J. Food Distribution Research.* 36: 1-8.
- Meyer, N. F., G. E. Erickson, T. J. Klopfenstein, M. A. Greenquist, M. K. Webbe, P. Williams and M. A. Engstrom. 2009. Effects of essential oils, tylosin, and monensin on finishing steer performance, carcass characteristics, liver abscesses, ruminal fermentation, and digestibility. *J. Anim. Sci.* 87: 2346-2354.
- Mir, Z., and P. Mir. 1994. Effect of addition of live yeast (*Saccharomyces cerevisiae*) on growth and carcass quality of steers fed high-forage or high-grain diets and on feed digestibility and in situ degradability. *J. Anim. Sci.* 72: 537-545.
- Montgomery, J. L., M. A. Carr, C. R. Kerth, G. G. Hilton, B. P. Price, M. L. Galyean, R. L. Horst and M. F. Miller. 2002. Effect of vitamin D₃ supplementation level on postmortem tenderization of beef from steers. *J. Anim. Sci.* 80: 971-981.

- Montgomery, J. L., C. R. Krehbiel, J. J. Cranston, D. A. Yates, J. P. Hutcheson, W. T. Nichols, M. N. Streeter, R. S. Swingle and T. H. Montgomery. 2009. Effects of dietary zilpaterol hydrochloride on feedlot performance and carcass characteristics of beef steers fed with and without monensin and tylosin. *J. Anim. Sci.* 87: 1013-1023.
- Montgomery, T., P. Dew, and M. Brown. 2001. Optimizing carcass value and the use of anabolic implants in beef cattle. *J. Anim. Sci.* 79: E296-E306.
- Moya, D., S. Calsamiglia, A. Ferret, M. Blanch, J. I. Fandiño, L. Castillejos and I. Yoon. 2009. Effects of dietary changes and yeast cultures (*Saccharomyces cerevisiae*) on rumen microbial fermentation of Holstein heifers. *J. Anim. Sci.* 87: 2874-2881.
- Napolitano, F., A. Braghieri, E. Piasentier, S. Farotto, S. Naspetti and R. Zanolli. 2010. Effect of information about organic production on beef liking and consumer willingness to pay. *Food Quality and Preference.* 21: 207-212.
- Newbold, D., R. Wallace, and F. McIntosh. 1996. Mode of action of the yeast *Saccharomyces cerevisiae* as a feed additive for ruminants. *British J. Nutrition.* 76: 294-262.
- Parr, S. L., K. Y. Chung, M. L. Galyean, J. P. Hutcheson, N. DiLorenzo, K. E. Hales, M. L. May, M. J. Quinn, D. R. Smith and B. J. Johnson. 2011. Performance of finishing beef steers in response to anabolic implant and zilpaterol hydrochloride supplementation. *J. Anim. Sci.* 89: 560-570.
- Pendlum, L., J. Boling, and N. Bradley. 1978. Levels of monensin with and without tylosin for growing-finishing steers. *J. Anim. Sci.* 47: 1-5.

- Peterson, R. E., T. J. Klopfenstein, G. E. Erickson, J. Folmer, S. Hinkley, R. A. Moxley and D. R. Smith. 2007. Effect of *Lactobacillus acidophilus* strain NP51 on *Escherichia coli* O157:H7 fecal shedding and finishing performance in beef feedlot cattle. Faculty Papers and Publications in Animal Science. 540
- Raun, A. P., C. O. Cooley, E. L. Potter, R. P. Rathmacher, L. F. Richardson. 1976. Effect of monensin on feed efficiency of feedlot cattle. J. Anim. Sci. 43: 670-677.
- Raun, A., and R. Preston. 2002. History of diethylstilbestrol use in cattle. Amer. Society of Anim. Sci. 1-7.
- Russel, J. B., and H. Strobel. 1989. Effect of ionophores on ruminal fermentation. Applied and Environmental Microbiology. 55: 1-6.
- Salminen, S., E. Isolauri, E. Salminen. 1996. Clinical uses of probiotics for stabilizing the gut mucosal barrier: successful strains and future challenges. Antonie Van Leeuwenhoek. 70: 347-358.
- Scramlin, S. M., W. J. Platter, R. A. Gomez, W. T. Choat, F. M. McKeith and J. Killefer. 2010. Comparative effects of ractopamine hydrochloride and zilpaterol hydrochloride on growth performance, carcass traits, and longissimus tenderness of finishing steers. J. Anim. Sci. 88: 1823-1829.
- Shen, Y. B., X. S. Piao, S. W. Kim, L. Wang, P. Liu, I. Yoon and Y. G. Zhen. 2009. Effects of yeast culture supplementation on growth performance, intestinal health, and immune response of nursery pigs. J. Anim. Sci. 87: 2614-2624.

- Sitz, B., C. R. Calkins, D. M. Feuz, W. J. Umberger, and K. M. Eskridge. 2005. Consumer sensory acceptance and value of domestic, Canadian, and Australian grass-fed beef steaks. *J. Anim. Sci.* 83: 2863-2868.
- Solomons, I. 1978. Antibiotics in animal feeds- Human and animal safety issues. *J. Anim. Sci.* 46: 557-564.
- Strydom, P., L. Frylinck, J. Montgomery, and M. Smith. 2009. The comparison of three β -agonists for growth performance, carcass characteristics and meat quality of feedlot cattle. *J. Meat Sci.* 81: 557-564.
- Strydom, P. L., M. Hope-Jones, L. Frylinck, E. C. Webb. 2011. The effects of beta-agonist treatment, vitamin D₃ supplementation and electrical stimulation on meat quality of feedlot steers. *J. Meat Sci.* 89:462-468.
- Swanek, S. S., J. B. Morgan, F. N. Owens, D. R. Gill, C. A. Strasia, H. G. Dolezal and F. K. Ray. 1999. Vitamin D₃ supplementation of beef steers increases longissimus tenderness. *J. Anim. Sci.* 77: 874-881.
- Umberger, W. J., D. M. Feuz, C. R. Calkins, and K. Killinger-Mann. 2002. US Consumer preference and willingness-to-pay for domestic corn-fed beef versus international grass-fed beef measured through an experimental auction. *Agribusiness.* 18: 491-504.
- USDA. 2013. Organic Foods Production Act Provisions: National Organic Program. Accessed Mar. 1, 2013. http://www.ecfr.gov/cgi-bin/text-idx?c=ecfr&sid=3f34f4c22f9aa8e6d9864cc2683cea02&tpl=/ecfrbrowse/Title07/7cfr205_main_02.tpl

- Woodward, B., and M. Fernandez. 1999. Comparison of conventional and organic beef production systems II. Carcass characteristics. *Livestock Production Sci.* 61: 225-231.
- Zobell, D. R., C. K. Chapman, K. Heaton, and C. Birkelo. 2000. Beef Cattle Implants. Archived USU Extension Publications.

CHAPTER II

INFLUENCE OF YEAST CELL WALL SUPPLEMENTATION DURING THE FINISHING PHASE ON FEEDLOT STEER PERFORMANCE, CARCASS CHARACTERISTICS AND POST-MORTEM TENDERNESS

Abstract

Objectives were to evaluate benefits of yeast cell wall (**YCW**) supplementation on performance, carcass traits and tenderness of steers finished with zilpaterol hydrochloride (**ZH**). A randomized complete block design was used. British X Continental steers ($n = 72$; initial BW = 305 ± 13 kg) were blocked by BW and allotted randomly to 24 pens (8 pens/treatment; 3 pens/block; 3 steers/pen). Treatments were: 1) control (**CON**); 2) YCW containing 100,000 IU vitamin D₂/g ($5.0 \text{ g} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$) (**Y-D**); 3) YCW C ($5.0 \text{ g} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$) (**Y-C**). Steers were supplemented with respective treatments for 55 d, of which ZH was fed d 30-49. Cattle were weighed at d 0, 21, and 55. Carcass data was collected at the plant, and strip loins were obtained. Strips were cut into steaks and assigned to one of four aging periods (7, 14, 21 or 28 d). Tenderness was examined using Warner-Bratzler shear force (**WBSF**). Shrink performance showed no differences. Carcass adjusted average daily gain (**ADG**) from d 21-55 was 0.29 kg greater for Y-D and 0.35 kg greater for Y-C when compared to CON ($P = 0.04$ and 0.01 , respectively). Additionally, YCW increased G:F from d 21-55 with a 20.77% improvement for Y-D and 28.46% for Y-C over CON ($P = 0.06$ and 0.01 , respectively). Carcass data revealed no differences, yet there was a trend for a 6 kg increase in HCW by both Y-D and Y-C compared to CON ($P = 0.16$ and 0.12). The treatment $\times$ aging interaction with the WBSF data was not significant ($P = 0.20$) and no differences were found in cooking loss ($P =$

0.88). Treatment Y-C displayed WBSF values 0.30 kg higher than CON and 0.29 kg greater than Y-D ($P = 0.0062$ and 0.0075). Within the 7 d aging period, Y-C steaks were 0.62 kg ($P = 0.005$) and 0.54 kg ($P = 0.014$) less tender than CON or Y-D, respectively. For 14 d steaks, Y-C WBSF values were 0.58 kg greater than CON ($P = 0.008$). No differences were found in the 21 or 28 d aging periods. The frequency distribution of WBSF values consistently displayed a trend for tougher Y-C steaks within each aging period. These data indicate yeast cell wall supplementation could increase performance of finishing steers while vitamin D₂ supplementation at the current dosage yielded no beneficial effects on tenderness.

Introduction

Efficiency dictates the success of the feedlot segment of beef cattle production. In an effort to increase profitability, technologies have emerged to promote growth and maintain health during the feeding phase. Unfortunately, the public perceives these products negatively based on their classification as antibiotics or growth promotants. There are natural options available to producers which aim to increase efficiency through modification of the gastrointestinal environment such as yeast products. *Saccharomyces cerevisiae* is a yeast culture evaluated for its effects on performance and immune function (Jurgens et al., 1997).

Performance data from yeast supplementation trials are conflicted. Because of its immune modification properties, yeast feed additives have most often been studied during the receiving period; however, there are times of stress during the finishing phase as well. Strydom et al. (2009) reported a significant decrease in dry matter intake (**DMI**)

of cattle fed zilpaterol hydrochloride (**ZH**) compared to control. Therefore, the application of yeast products, during times of metabolic stress is of interest.

Multiple studies have reported decreased tenderness with ZH (Brooks et al., 2009; Strydom et al., 2009; Rathmann et al., 2012). It has been postulated that supplemental vitamin D may rectify these effects on meat quality. Of the two forms of the vitamin available, vitamin D₃ has been the most extensively studied in terms of altering tenderness (Swanek et al., 1999; Montgomery et al., 2002; Hansen et al., 2012). Little research exists concerning the use of vitamin D₂ in livestock, creating a need for more data to establish its value in beef cattle production. In the case that both vitamin D forms can be used interchangeably, this data indicates that a yeast product high in vitamin D₂ may provide advantages in performance and tenderness while feeding ZH. The objectives of this study were to evaluate benefits of yeast cell wall (**YCW**) supplementation on performance, carcass traits and tenderness of steers finished with ZH.

Materials and Methods

All procedures involving live animals were approved (#12047-06) by the Texas Tech University Animal Care and Use Committee.

Live Performance and Carcass Characteristics

Cattle

On April 24, 2012, British X Continental crossbred steers (n=80; 305 ± 13 kg) were delivered to the Texas Tech University Beef Center in New Deal, TX. Steers were placed in a large group pen and offered *ad libitum* access to Prairie hay on the day of arrival. The following day, steers received a 65% concentrate receiving diet and were

stepped up over the next 50 days onto a 90% concentrate finishing ration (Tables 2.1-2). Cattle had been processed and implanted prior to arrival and were treated metaphylactically (Excede, Zoetis Animal Health, Madison, NJ) 7 d post arrival. Steers were weighed once again on August 1, 2012 and continued housing in a group pen.

Experimental Design, Treatment, and Pen Assignment

Steers were re-weighed on d 0 (September 12, 2012) with Silencer squeeze chute (Moly Manufacturing, Inc., Lorraine, KS; accuracy ± 0.5 kg) and blocked by BW (n=8; 534 ± 28 kg). Within a block, 3 treatments were assigned to pens using a randomized block design (24 pens; 8 pens/treatment; 3 steers/pen). Of the 80 steers delivered, the 72 animals most uniform in BW and frame size were selected for this study. Treatments were as follows: 1) control (**CON**); 2) YCW derived from *Saccharomyces cerevisiae* containing 100,000 IU vitamin D₂/gram ($5.0 \text{ g} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$) (**Y-D**); 3) YCW C; a YCW derived from *Saccharomyces cerevisiae* ($5.0 \text{ g} \cdot \text{hd}^{-1} \cdot \text{d}^{-1}$) (**Y-C**). Once BW was recorded, and cattle were sorted into their home pen (3 m x 9.1 m pipe feedlot pens; with a dirt floor and concrete aprons around water troughs and feed bunks).

Management and Treatment Application

Cattle were fed once daily in the morning (0900 to 1000 h) and feed delivery was adjusted to provide *ad libitum* access to feed while reducing waste. The feeding order throughout the trial was in numerical pen order. Feed was mixed and delivered daily in a drag type Rotomix feed wagon (Dodge City, KS). Cattle were fed a 90% concentrate ration throughout the study. Treatments were top-dressed in feed bunks daily at a rate of 5.0 g YCW per head.

All premixes were made at the Texas Tech University Burnett Center Feed Mill in a paddle type mixer (Marion Mixers Inc.). The supplement premix included standard trace minerals, vitamins, monensin (Rumensin 90, Elanco Animal Health, Greenfield, IN), and tylosin (Tylan 40, Elanco Animal Health, Greenfield, IN). Ingredients for the YCW premix included ground corn and YCW (excluded in the control premix). Yeast cell wall was measured out into a clean bowl on a Mettler (Novatech UK Limited, United Kingdom) electronic balance (accuracy ± 1.0 g). Ground corn was measured on a Mettler (Novatech UK Limited, United Kingdom) electronic balance (accuracy ± 4.5 g). Ground corn was added first, followed the appropriate quantity and type of yeast cell wall and allowed to mix for 5 minutes. Once mixed, each premix was dispensed in to the respective treatment barrel. Samples were taken as the premix was dispensed from the mixer. The mixer was swept and blown out with pressurized air between each premix to help decrease contamination. Yeast cell wall premixes were weighed out for each pen daily into plastic containers with corresponding numbered lids. Diet samples were taken weekly and dried in a forced-air oven at 100°C for approximately 24 h to determine dry matter (**DM**) content. Weights for DM determination were taken on an Ohaus (Pine Brook, NJ) electronic balance (accuracy ± 0.1 g). Representative bunk samples for feeding periods with and without ZH were sent to a commercial laboratory for composition analysis.

At approximately 0600 h on the morning of each weigh day (d 21 and 55) feed refusals were collected and weighed, and a sample of remaining feed was dried as described above to determine the DM content. The DMI by each pen was calculated by

subtracting the quantity of dry feed unconsumed at the end of every weigh period from the total dietary DM delivered to each pen during that period.

Unshrunk body weight (**BW**) measurements were taken on d 21 and d 55 before the daily feeding between 0630 and 0800 h. Weights taken on d 21 used a large pen scale (Cardinal Scale Manufacturing Co., Webb City, MO; accuracy ± 2.7 kg). Cattle health was evaluated daily between 0700 and 0800 for signs of illness or injury. No cattle showed signs of illness requiring treatment during the course of this study.

Zilpaterol hydrochloride (Zilmax, Merck Animal Health, Summit, NJ) supplementation began on d 30 of the study and continued for the following 20 days. Type A ZH was mixed with ground corn to create a type B supplement in the same manner and with the same equipment used for the yeast cell wall premix. The mixing ratio ensured that when the type B premix was included at a rate of 0.5% of the ration, it would provide 8.3 mg ZH/kg ration on a DM basis. This would satisfy the manufacturer's recommended dosage of 60 to 90 mg/hd/d. Zilpaterol hydrochloride was excluded from the diet starting on d 50 and all bunks were cleaned of refusals that morning to ensure the proper withdrawal (minimum 3 d) period was allowed.

On d 55, BW was measured individually using a Silencer squeeze chute (Moly Manufacturing, Inc., Lorraine, KS; accuracy ± 0.5 kg) and steers were returned to their home pens. The following morning, steers were loaded onto two trucks and sent to harvest at Tyson Fresh Meats, Inc., Amarillo, TX. Individual carcass measurements were collected by trained Texas Tech University personnel as previously described by Brown

and Lawrence (2010). Full loins were also collected from each steer for later analysis of tenderness.

Post-Mortem Tenderness

Steak Handling

On d 6 post-mortem, the strip loins were fabricated into steaks 2.54 cm thick. The anterior-most end of the strip was removed to level the face of the subprimal cut. The next 4 steaks were assigned to 1 of 4 aging periods (7, 14, 21, 28 d postmortem) in rotating order to ensure each aging period was equally represented among anatomical position within the loin. Steaks were vacuum packaged in groups of 8 within the same aging period and stored at 2°C. After the appropriate aging period, steaks were frozen at -20°C until later analysis.

Warner-Bratzler Shear Force

Steaks (n=288) were thawed between 2 to 4°C for 19 hours prior to cooking. Internal steak temperature was checked before being placed on the grill and was required to be between 2 and 5°C. Cooking was done using a Magigrill belt grill (Magi-Kitch'n Inc., Quakertown, PA) to an internal temperature of 71°C (range of 68-72°C). Temperature was monitored with a digital meat thermometer (Cooper Instruments, Middlefield, CT). Weights were taken on individual steaks both prior to cooking and after to determine cooking loss. Cooked steaks were placed on metal trays and chilled at 2°C for 24 hours.

Once chilled, Warner-Bratzler shear force (**WBSF**) values were obtained by removing 6 cores, 1.3 cm in diameter, parallel to the muscle fiber and with evenly

distributed samples among the entire steak. Cores were sheared perpendicular to the muscle fibers with a WBSF analyzer (G-R Electric Manufacturing, Manhattan, KS). The Warner-Bratzler head moved at a crosshead speed of 200 mm/min and values were recorded in kilograms. The six values were averaged for each steak, and were again averaged by pen for statistical analysis.

Statistical Analysis

For all analysis, pen was considered the experimental unit and pen averages were calculated. Performance was analyzed with two different sets of calculations. Carcass adjusted BW was calculated using the average dressing percent of the cattle and shrunk BW was calculated by shrinking all BW by 4%. Carcass adjusted and shrunk performance traits were then derived from these BW values. Block 1 was excluded from analysis as animals went off treatment due to a facility malfunction. Live performance and carcass data were analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC) in a linear mixed model with treatment as a fixed effect and blocked on initial body weight. Contrasts were run on both DMI and HCW data comparing pooled YCW treatment means to CON and comparing Y-D to Y-C. Cooking loss and WBSF values were also analyzed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC) but included treatment and aging period as fixed effects. Distribution of quality grade, yield grade and WBSF values was calculated using the GLIMMIX procedure of SAS(SAS Inst., Inc., Cary, NC). P -value of ≤ 0.10 was considered significant.

Results

Live Performance and Carcass Characteristics

There were no differences in shrunk performance between any of the dietary treatments (Table 2.3). However, the evaluation of carcass adjusted performance showed benefits of yeast cell wall supplementation (Table 2.4). Carcass adjusted average daily gain (**ADG**) for d 21 to 55 was 0.29 kg greater for Y-D and 0.35 kg greater for Y-C when compared to CON ($P = 0.04$ and 0.01 , respectively). Additionally, benefits in efficiency were observed as Y-D and Y-C improved G:F by 20.77 % ($P = 0.06$) and 28.46 % ($P = 0.01$), respectively, compared to CON. Contrasts were run comparing Y-D to Y-C and pooled YCW means to CON for DMI of all feeding periods and no differences were found. Carcass data is illustrated in Table 2.5. There was a trend for a 6 kg increase in HCW by both treatments Y-D and Y-C compared to CON ($P = 0.16$ and 0.12 respectively). When a contrast was run, there was no difference between either YCW treatments ($P = 0.88$) however there was a difference between the pooled means of the YCW treatments compared to CON ($P = 0.094$). Therefore it appeared the increased performance during the ZH feeding period resulted in increased HCW. No other carcass traits were affected by yeast supplementation.

Post-Mortem Tenderness

The treatment $\times$ aging interaction was not significant ($P = 0.20$), therefore treatment effects may be examined despite aging period. No differences were found in cooking loss data. Values of WBSF for Y-C were 0.30 kg higher than CON and 0.29 kg higher than Y-D ($P = 0.0062$ and 0.0075 respectively) indicating that steaks from cattle

fed Y-C were less tender (Table 2.6). Within the 7 d aging period, WBSF values for Y-C steaks were 0.62 kg ($P = 0.005$) and 0.54 kg ($P = 0.014$) greater than CON or Y-D, respectively (Table 2.7). For steaks aged 14 d, Y-C WBSF values were 0.58 kg greater than CON steaks ($P = 0.008$) (Table 2.7). There were no other significant differences detected for the 21 or 28 d aging periods. When looking at the frequency distribution of WBSF values within given ranges, treatment Y-C consistently displayed higher values within each aging period (Figures 2.1-4).

Discussion

Yeast feed supplements are thought to increase performance and animal health by acting as an immune modifier. *Saccharomyces cerevisiae* is a yeast culture that is evaluated for its effects on animal performance and immune function (Jurgens et al., 1997). In an in vitro study, Newbold et al. (1996) reported that the mode of action of *Saccharomyces cerevisiae* in ruminants stem from their respiratory activity in the rumen. The yeast culture increased O₂ disappearance and stimulated both the total and cellulolytic bacteria populations (Newbold et al., 1996).

Because of the immune modification aspect of yeast feed additives, their application is often studied during times of stress. Cole et al. (1992) reported that yeast culture had beneficial effects on feeder calf morbidity and DMI, yet this effect is more pronounced in stressed calves. The receiving period can be a time of great stress for feedlot cattle, and as a result has been a focus of studies involving yeast products. However, the ZH feeding period is another stressful period in the feedyard. Strydom et al. (2009) reported a significant decrease in DMI of cattle fed ZH compared to control cattle.

Therefore, the application of immune modifiers, such as yeast products, during a time of metabolic stress is of interest.

In a receiving trial study previously conducted at the Texas Tech University Beef Center using the same yeast cell wall as the current study's Y-C treatment, Young (2012) found increased DMI, ADG, and BW in stressed beef heifers. While this study found no differences in DMI, the data showed a similar increase in ADG with the added benefit of increased feed efficiency. Furthermore, the increase in BW found in the previous study may account for the trend seen in greater HCW. In addition, Young (2012) found that YCW-C resulted in improved feedlot performance following both an LPS and heat stress challenge. Collectively, it appears that feeding YCW during periods of either external (LPS; heat) or metabolic (ZH feeding) stress results in improved gain, efficiency and DMI in feedlot cattle.

Another main objective of this study was to analyze the effects of the yeast cell wall supplementation, and more specifically, the influence of added vitamin D₂ on longissimus dorsi tenderness. There are two forms of supplemental vitamin D available: ergocalciferol (vitamin D₂) and cholecalciferol (vitamin D₃) (Haughton and Vieth, 2006). Of the two forms, vitamin D₃ has been the most extensively studied supplement in terms of altering tenderness. Swanek et al. (1999) explains the mechanism of vitamin D₃ supplementation as increasing blood calcium concentration, which in turn increases calpain activity. Montgomery et al. (2002) reported that vitamin D₃ increased tenderness in muscles with a tendency to be tough, but had no effect on cuts accepted as tender. When supplemented in conjunction with ZH, Hansen et al. (2012) found vitamin D₃ had

no effect on WBSF but did shorten myofibrillar length, suggesting that differences in tenderness may not have been pronounced enough to be considered significant in the WBSF. Furthermore, in another study supplementing vitamin D₃ with ZH, some short term dosages of vitamin D₃ displayed beneficial effects on tenderness; however, electrical stimulation was more effective at reversing ZH induced toughness (Strydom et al., 2011).

Unfortunately, vitamin D₃ has been criticized as a potentially toxic feed supplement. Montgomery et al. (2002) explained that vitamin D₃ toxicity can result in prolonged hypercalcemia, decreased performance, and death. Additionally, the dosage of vitamin D₃ necessary to see the beneficial effects on tenderness are considered to be potentially toxic (Montgomery et al., 2002).

Interestingly, Y-C cattle yielded significantly tougher steaks. However, data revealed no advantages in tenderness of cattle fed a YCW with vitamin D₂ (Y-D) in conjunction with ZH supplementation. Tenderness benefits of vitamin D₂ supplementation may have been masked due to the dosage administered in this study. Cattle in treatment Y-D were fed approximately 500,000 IU of vitamin D₂/hd/d while Montgomery et al. (2002) reported that vitamin D₃ must be fed at levels of 5,000,000 IU/hd/d and higher in order to see benefits in WBSF values. Unfortunately at that level of supplementation, ADG was reduced and feeding 2,500,000 IU/hd/d and higher decreased DMI (Montgomery et al., 2002). Additionally, the dosage of vitamin D₃ necessary to see the beneficial effects on tenderness are considered to be potentially toxic (Montgomery et al., 2002). This raises interest in vitamin D₂ as a potentially safer alternative.

Research disagrees whether the two forms of vitamin D can be used interchangeably. Houghton and Vieth (2006) explains that vitamin D₃ is a more potent form of the vitamin, This may account for the decreased incidence of toxicity seen with vitamin D₂ supplementation. Still, being that vitamin D₃ is a more concentrated form, it brings to question if they illicit the same response. Holick et al. (2008) has shown both forms to be equally effective in maintaining serum 25-hydroxyvitamin D levels. Houghton and Vieth (2006) reported opposing results, stating that 25-hydroxyvitamin D levels were higher in people supplemented vitamin D₃ compared to its counterpart. Not enough research has been done comparing the effectiveness of the two forms of vitamin D in livestock, and more specifically in ruminant animals. Therefore, this study is the first data collected referring to vitamin D₂ supplementation in beef cattle. This data indicates that a study feeding higher levels of vitamin D₂ may be necessary to determine if tenderness benefits may be observed without compromising live performance.

Conclusions

Yeast cell wall supplementation does seem to be an effective and natural option to increase performance and alleviate both external and metabolic stress in feedlot steers. Cattle fed either YCW supplement displayed greater efficiency and ADG during the last 34 days of the finishing phase. A YCW supplement high in vitamin D₂ did not prove to be an effective means of reversing ZH induced toughness at the current dose, however previous research indicates that additional dosages should be investigated before determining the vitamin's application in the industry.

Tables and Figures

Table 2.1. Dry matter composition of 90% concentrate finishing diet.

Ingredient	%, Dry Matter Basis
Steam Flaked Corn ¹	73.51
Cottonseed Hulls	5.25
Chopped Alfalfa	5.22
Cottonseed Meal	4.71
Urea	0.94
TTU Supplement ²	2.33
Calcium Carbonate	0.89
Molasses	4.19
Animal Fat	2.69

¹0.5% ground corn based ZH premix substituted for steam flaked corn d 30-49²Provides 29.9 g/ton Rumensin and 10.0 g/ton TylanTable 2.2. Nutrient analysis of 90% concentrate finishing diet on a dry matter¹ basis.

Item	Feeding Period	
	d 0-29	d 30-54 ²
Dry Matter, %	83.2	83.7
Crude Protein, %	13.6	14.1
Crude Fiber, %	7.8	7.4
Crude Fat, %	5.1	5.0
Total Digestible Nutrients, %	87.0	87.7
Net Energy, Maint, Mcal/kg	2.16	2.18
Net Energy, Gain, Mcal/kg	1.48	1.50
Digestible Energy, Mcal/kg	3.84	3.88
ME, Mcal/kg	3.15	3.18
Calcium, %	0.43	0.49
Phosphorus, %	0.30	0.30

¹All values provided on a dry matter basis except % Dry Matter²Zilpaterol hydrochloride feeding period and withdrawal.

Table 2.3. Effects of yeast cell wall supplementation during the finishing phase on shrunk beef cattle performance.

Item ³	Treatment ¹			SEM ²	P-value
	CON	Y-D	Y-C		
Pens	7	7	7		
4% adjusted BW, kg ⁴					
d 0	513	512	513	0.4	0.40
d 21	553	552	550	2.8	0.65
d 55	603	601	604	5.0	0.86
ADG, kg					
d 0-21	1.94	1.87	1.79	0.132	0.54
d 21-55	1.44	1.45	1.56	0.103	0.50
d 0-55	1.52	1.50	1.54	0.085	0.88
G:F					
d 0-21	0.184	0.176	0.170	0.0142	0.61
d 21-55	0.169	0.158	0.155	0.0139	0.56
d 0-55	0.147	0.146	0.159	0.0098	0.36
DMI, kg					
d 0-21	9.42	9.42	9.35	0.063	0.49
d 21-55	9.88	10.07	9.88	0.278	0.74
d 0-55	9.75	9.87	9.73	0.192	0.74
ZH feeding period ⁵	9.65	9.78	9.84	0.223	0.68

¹CON = control; Y-D = yeast cell wall containing 100,000 IU of vitamin D₂/g; Y-C = YCW C, yeast cell wall derived from *Saccharomyces cerevisiae*.

²Pooled standard error of the mean

³Three feeding periods analyzed: the first 21 days, the last 34 days, and the entire 55 days of supplementation.

⁴Calculated as BW shrunk 4%. Subsequent ADG, F:G, and G:F calculated from these BW calculations

⁵Day 30-49 of study, the period when zilpaterol hydrochloride was administered

Table 2.4. Effects of yeast cell wall supplementation during the finishing phase on carcass adjusted beef cattle performance.

Item ³	Treatment ¹			SEM ²	P-value
	CON	Y-D	Y-C		
Pens	7	7	7		
Carcass Adjusted Final BW, kg ⁴	597	605	607	5.5	0.21
ADG, kg					
Day 21-55	1.29 ^a	1.58 ^b	1.64 ^b	0.124	0.03
Day 0-55	1.43	1.59	1.60	0.097	0.20
G:F					
Day 21-55	0.130 ^{a,c}	0.157 ^d	0.167 ^{b,d}	0.0130	0.04
Day 0-55	0.147	0.161	0.165	0.0107	0.24
Dressing percent ⁵	66.97	68.06	67.91	0.728	0.30

¹CON = control; Y-D = yeast cell wall containing 100,000 IU of vitamin D₂/g; Y-C = YCW C, yeast cell wall derived from *Saccharomyces cerevisiae*.

²Pooled standard error of the mean

³Two feeding periods analyzed: the last 34 days and the whole 55 days of supplementation.

⁴Calculated as HCW shrunk divided by 0.6752. Subsequent ADG, F:G, and G:F calculated from this final BW calculation

⁵Calculated as HCW divided by 4% adjusted final BW

^{a-b}Within a row, means that do not have a common superscript differ, $P < 0.05$

^{c-d}Within a row, means that do not have a common superscript differ, $P < 0.10$

Table 2.5. Effects of yeast cell wall supplementation during the finishing phase on beef carcass characteristics.

Item	Treatment ¹			SEM ²	P-value
	CON	Y-D	Y-C		
Pens	7	7	7		
HCW, kg	403	409	409	3.62	0.23
LM area, cm ²	103.42	103.82	106.40	3.729	0.69
12 th rib fat ³ , cm	0.94	1.02	1.04	0.109	0.57
KPH, %	1.79	1.86	1.92	0.111	0.47
APYG ⁴	3.01	3.11	3.13	0.108	0.50
Yield Grade ⁵	2.02	2.16	2.06	0.244	0.84
< 2, %	28.57	42.86	42.86	27.766	0.84
2- < 3, %	71.43	42.86	57.14	27.766	0.60
3- < 4, %	0	14.29	0	11.664	0.39
Marbling Score ⁶	382	420	387	31.0	0.43
Quality Grade, %					
Premium Choice	0	14.29	0	11.664	0.38
Choice Minus	28.57	42.86	42.86	27.766	0.84
Select	71.43	42.86	57.14	27.766	0.60
Color Score ⁷	4.62	4.71	4.62	0.225	0.89

¹CON = control; Y-D = yeast cell wall containing 100,000 IU of vitamin D₂/g; Y-C = YCW C, yeast cell wall derived from *Saccharomyces cerevisiae*.

²Pooled standard error of the mean

³Calculated using: Fat thickness=(PYG-2.0)/2.5

⁴Adjusted preliminary yield grade

⁵Calculated using: Yield Grade = 2.5 + (2.5*FT) + (0.2*KPH%) + (0.0038*HCW) - (0.32*REA)

⁶Marbling score: 300=Slight⁰⁰; 400=Small⁰⁰

⁷1= light pink ; 5= cherry red

Table 2.6. Effects of yeast cell wall supplementation on Warner-Bratzler shear force of beef longissimus dorsi.

	Treatment* ¹			SEM ²	P-value
	CON	Y-D	Y-C		
WBSF, kg	4.02 ^a	4.03 ^a	4.32 ^b	0.075	0.0079
Purge ³ , %	16.03	16.09	16.49	0.580	0.70
Cooking Loss ⁴ , %	19.75	19.89	19.81	0.183	0.88

*Note: Treatment × Aging interaction, $P = 0.20$

¹CON = control; Y-D = yeast cell wall containing 100,000 IU of vitamin D₂/g; Y-C = YCW C, yeast cell wall derived from *Saccharomyces cerevisiae*.

²Pooled standard error of the mean

³Calculated as [(wet wt-dry wt)/wet wt] x 100

⁴Cooking loss % = [(raw wt(g) – cooked wt(g))/raw wt(g)] x 100

^{a-b}Within a row, means that do not have a common superscript differ, $P < 0.05$

Table 2.7. Effects of yeast cell wall¹ supplementation during the finishing phase on Warner-Bratzler shear force and cooking loss of beef longissimus dorsi by aging period².

Item	7 Days			14 Days			21 Days			28 Days			SEM ³
	CON	Y-D	Y-C	CON	Y-D	Y-C	CON	Y-D	Y-C	CON	Y-D	Y-C	
Pens	7	7	7	7	7	7	7	7	7	7	7	7	
WBSF ⁴ , kg	5.02 ^a	5.10 ^a	5.64 ^b	3.81 ^a	4.05 ^{a,b}	4.39 ^b	3.81	3.60	3.84	3.44	3.36	3.42	0.150
Cooking loss, ⁵ %	19.56	19.87	19.96	19.70	19.84	19.90	20.02	20.09	19.73	19.72	19.71	19.64	0.366

¹CON = control; Y-D = yeast cell wall containing 100,000 IU of vitamin D₂/g; Y-C = YCW C, yeast cell wall derived from *Saccharomyces cerevisiae*.

²4 aging periods: 7, 14, 21, and 28 days

³ Pooled standard error of the mean

⁴Warner-Bratzler shear force

⁵Cooking loss % = [(raw wt(g) – cooked wt(g))/raw wt(g)] x 100

^{a-b}Within a row, means that do not have a common superscript differ, $P < 0.05$

^{c-d}Within a row, means that do not have a common superscript differ, $P < 0.10$

Figure 2.1. Influence of yeast cell wall¹ supplementation during the finishing phase on tenderness of beef longissimus dorsi aged 7 days. ¹CON = control; Y-D = yeast cell wall containing 100,000 IU of vitamin D₂/g; Y-C = YCW C, yeast cell wall derived from *Saccharomyces cerevisiae*. The SE of the difference between treatment frequency for range 4.00-4.29 kg = 8.248 %; 4.30-4.99 kg = 15.794 %; and > 5.00 kg = 16.496 %.

Figure 2.2. Influence of yeast cell wall¹ supplementation during the finishing phase on tenderness of beef longissimus dorsi aged 14 days. ¹CON = control; Y-D = yeast cell wall containing 100,000 IU of vitamin D₂/g; Y-C = YCW C, yeast cell wall derived from *Saccharomyces cerevisiae*. The SE of the difference between treatment frequency for range 3.00-3.39 kg = 10.648 %; 3.40-3.99 kg = 17.817 %; 4.00-4.29 kg = 19.048 %; 4.30-4.99 kg = 16.496 %; and >5.00 kg = 8.248 %.

Figure 2.3. Influence of yeast cell wall¹ supplementation during the finishing phase on tenderness of beef longissimus dorsi aged 21 days. ¹CON = control; Y-D = yeast cell wall containing 100,000 IU of vitamin D₂/g; Y-C = YCW C, yeast cell wall derived from *Saccharomyces cerevisiae*. The SE of the difference between treatment frequency for range 3.00-3.39 kg = 13.469 %; 3.40-3.99 kg = 19.634 %; 4.00-4.29 kg = 15.794 %; and 4.30-4.99 kg = 8.248 %.

Figure 2.4. Influence of yeast cell wall¹ supplementation during the finishing phase on tenderness of beef longissimus dorsi aged 28 days. ¹CON = control; Y-D = yeast cell wall containing 100,000 IU of vitamin D₂/g; Y-C = YCW C, yeast cell wall derived from *Saccharomyces cerevisiae*. The SE of the difference between treatment frequency for range <3.00 kg = 13.496 %; 3.00-3.39 kg = 17.817 %; and 3.40-3.99 kg = 20.203 %.

Literature Cited

- Brooks, J. C., H. C. Claus, M. E. Dikeman, J. Shook, G. G. Hilton, T. E. Lawrence, J. M. Mehaffey, B. J. Johnson, D. M. Allen, M. N. Streeter, W. T. Nichols, J. P. Hutcheson, D. A. Yates and M. F. Miller. 2009. Effects of zilpaterol hydrochloride feeding duration and postmortem aging on Warner-Bratzler shear force of three muscles from beef steers and heifers. *J. Anim. Sci.* 87: 3764-3769.
- Brown, T. R., and T. E. Lawrence. 2010. Influence of phenotypic hide color and sex condition on beef carcass grading performance and value. *The Professional Anim. Scientist.* 26: 611-619.
- Cole, N., C. Purdy, and D. Hutcheson. 1992. Influence of yeast culture on feeder calves and lambs. *J. Anim. Sci.* 70: 1682-1690.
- Hansen, S., L. Frylinck, and P. E. Strydom. 2012. The effect of vitamin D₃ supplementation on texture and oxidative stability of beef loins from steers treated with zilpaterol hydrochloride. *J. Meat Sci.* 90: 145-151.
- Holick, M. F., R. M. Biancuzzo, T. C. Chen, E. K. Klein, A. Young, D. Bibuld, R. Reitz, W. Salameh, A. Ameri and A. D. Tannenbaum. 2008. Vitamin D₂ is as effective as vitamin D₃ in maintaining circulating concentrations of 25-hydroxyvitamin D. *J. Clinical Endocrinology & Metabolism.* 93: 677-681.
- Houghton, L. A., and R. Veith. 2006. The case against ergocalciferol (vitamin D₂) as a vitamin supplement. *Amer. J. Clinical Nutrition.* 84: 694-697.

- Jurgens, M., R. Rikabi, and D. Zimmerman. 1997. The effect of dietary active dry yeast supplement on performance of sows during gestation-lactation and their pigs. *J. Anim. Sci.* 75: 593-597.
- Montgomery, J. L., M. A. Carr, C. R. Kerth, G. G. Hilton, B. P. Price, M. L. Galyean, R. L. Horst and M. F. Miller. 2002. Effect of vitamin D₃ supplementation level on postmortem tenderization of beef from steers. *J. Anim. Sci.* 80: 971-981.
- Newbold, D., R. Wallace, and F. McIntosh. 1996. Mode of action of the yeast *Saccharomyces cerevisiae* as a feed additive for ruminants. *British J. Nutrition.* 76: 294-262.
- Parr, S. L., K. Y. Chung, M. L. Galyean, J. P. Hutcheson, N. DiLorenzo, K. E. Hales, M. L. May, M. J. Quinn, D. R. Smith and B. J. Johnson. 2011. Performance of finishing beef steers in response to anabolic implant and zilpaterol hydrochloride supplementation. *J. Anim. Sci.* 89: 560-570.
- Pendlum, L., J. Boling, and N. Bradley. 1978. Levels of monensin with and without tylosin for growing-finishing steers. *J. Anim. Sci.* 47: 1-5.
- Rathmann, R. J., J. M. Mehaffey, T. J. Baxa, W. T. Nichols, D. A. Yates, J. P. Hutcheson, J. C. Brooks, B. J. Johnson and M. F. Miller. 2012. Effects of zilpaterol hydrochloride and days on the finishing diet on feedlot performance, carcass characteristics, and tenderness in beef heifers. *J. Anim. Sci.* 90: 3301-3311.
- Strydom, P., L. Frylinck, J. Montgomery, and M. Smith. 2009. The comparison of three β -agonists for growth performance, carcass characteristics and meat quality of feedlot cattle. *J. Meat Sci.* 81: 557-564.

- Strydom, P. L., M. Hope-Jones, L. Frylinck, E. C. Webb. 2011. The effects of beta-agonist treatment, vitamin D₃ supplementation and electrical stimulation on meat quality of feedlot steers. *J. Meat Sci.* 89:462-468.
- Swanek, S. S., J. B. Morgan, F. N. Owens, D. R. Gill, C. A. Strasia, H. G. Dolezal and F. K. Ray. 1999. Vitamin D₃ supplementation of beef steers increases longissimus tenderness. *J. Anim. Sci.* 77: 874-881.