EFFECTS OF *SACCHAROMYCES CEREVISIAE* SUPPLEMENTATION DURING RECEIVING AND FINISHING PERIODS ON GROWTH, EFFICIENCY, BEHAVIORAL AND HEALTH RESPONSES IN BEEF CATTLE

A Thesis

by

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ABSTRACT

Objectives of Study I were to evaluate the effects of live yeast (LY; *Saccharomyces cerevisiae boulardii* strain I-1079; 0.35 x 10^9 cfu/g ProTernative™) supplementation during the receiving period on growth efficiency, feeding behavior, activity and vaginal temperature in 72 newly weaned beef heifers (initial BW of 203 ± 22 kg). Heifers were shipped stressed before being allotted to 1 of 4 pens each equipped with 3 GrowSafe feed bunks, and assigned to 1 of 2 treatments (n = 36) consisting of standard receiving diet (ME 2.36 Mcal/kg, CP 16.5% DM) without LY, and control diet containing LY (5 g ProTernative/kg diet; Lallemand Animal Nutrition). Temperature sensors (iButton™) were placed intra-vaginally to record temperature, and accelerometer devices (HOBO™) attached (hind leg) to measure physical activity for the first 14 d (n = 18). LY treatment did not affect morbidity rate (10.4%), vaginal temperature (39.2 ± 0.2 °C), or frequency (16.6 ± 2.2 events/d) and duration (46 ± 5 min/event) of standing bouts. ADG tended ($P < 0.1$) to be greater for LY heifers during the first 28 d (0.625 vs 0.432 ± 0.08 kg/d), but was not affected by LY treatment during the 56-d study. LY heifers consumed more ($P < 0.05$) meals (16.8 vs 14.6 vs. ± 1.1 events/d) that were shorter ($P = 0.08$) in length (12.8 vs 14.9 ± 1.2 min/event) and smaller ($P < 0.05$) in size (0.48 vs 0.55 ± 0.04 kg/event) compared to control heifers. Moreover, heterogeneities of DMI (SD = 0.59 vs 0.92 kg/d) and RFI (SD = 0.48 vs 0.73 kg/d) were less ($P < 0.05$) in LY than control heifers.

Objectives of Study II were to evaluate the effects of LY (*Saccharomyces*

cerevisiae strain CNCM I-1077; 0.35 x 10^9 cfu/g Levucell™) supplementation during the receiving period on growth efficiency, feeding behavior, activity and ruminal temperature in 72 finishing beef steers (initial BW of 435 ± 27 kg). Steers were allotted to 1 of 6 pens each equipped with GrowSafe feed bunks, and assigned to 1 of 3 treatments (n = 24) consisting of standard finishing diet (ME 1.84 Mcal/kg, CP 12.7% DM) without LY, and control diet containing LY (4.5 g Levucell SC/kg diet; Lallemand Animal Nutrition) or control diet containing LY + extract (4.5 g Levucell SC + extract/kg diet; Lallemand Animal Nutrition). Ruminal temperature sensors (BellaAg) were placed, and accelerometer devices (HOBO™) attached (hind leg) to measure physical activity 14 d intervals during the 70 d trial (n = 30). LY treatment did not affect ruminal temperature (39.7 ± 0.1 °C), or frequency (13.9 ± 5.94 events/d) and duration (58.6 ± 1.47 min/event) of standing bouts. LY treatment did not affect performance, growth, or carcass traits in finishing steers. LY steers consumed meals that were longer ($P = 0.04$) in length (19.81 vs 15.4 and 17 ± 1.2 min/event) and at a slower ($P < 0.01$) eating rate (79.9 vs 102.1 and 98.8 ± 4.37 g/min) compared to control and LY + extract steers.

Supplementation with LY may have favorably affected meal patterns of newly weaned beef heifers and in finishing steers. LY treatment did not affect growth efficiency, health status, internal temperature, or physical activity in newly weaned heifers or in finishing steers.

DEDICATION

I would like to dedicate this thesis to my family who have provided endless love and support in me pursuing my dreams so far from home. I would also like to dedicate this to my wonderful boyfriend who has helped to keep me motivated and gave me many words of encouragement through this process. And to Tri-Tip for always being there for me.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Introduction

Beef cattle production in the United States is one of the largest produced commodities in agriculture. Beef is the most exported animal protein (by value) in the United States, controlling 5.09% of the total US export market (Cook, 2015). The FAO has recently projected that demand for meat and dairy protein products will nearly double by 2050 (FAO, 2012), due to continued increases in population growth and rising per capita incomes. To meet this increasing global demand for animal protein, there is a need for innovative and cost-effective technology to improve feed efficiency. Additionally, with growing societal concerns about the impact of livestock production systems on the environment and antibiotic resistance from consumers, further refinement of technologies are needed to promote more judicious use of antimicrobial products. These technologies have the potential to not only improve animal health, but increase efficiency of individual animals, ultimately increasing overall production. Focusing on reducing stress in cattle could be a way to help producers at all stages of production.

Stress is defined as a state of mental or emotional strain or tension, resulting from adverse or very demanding circumstances (Merriam-Webster, 2015). In the beef industry, cattle are exposed to stress at many different stages throughout their life. Undue and excessive stress leads to negative effects on performance of animals and feed efficiency, which increases the cost of gain, and negatively impacts the economic

sustainability of the beef industry, especially in young calves and growing cattle (Gaylean et al., 1999). Some stressors that lead to negative effects in beef cattle include weaning (Arthington et al, 2005), shipping stress (Arthington et al, 2008), commingling (Arthington et al, 2003), and heat stress (St. Pierre, 2003). Animals exposed to multiple stressors tend to have lower feed intakes and suppressed immune responses that may result in an increase in morbidity and mortality rates (Sowell et al., 1999). Development of strategies to mitigate the impact of these stressors in order to reduce the negative effects on beef cattle could improve cattle performance and feed efficiency as well as improve animal welfare.

Many studies have examined the effects of various management strategies to reduce stress or mitigating its effects on animal productivity in studies that used pen as the experimental unit. However, few studies have been conducted to examine the effects of various management strategies on productivity and behavioral responses on an individual-animal basis (DeVries et al, 2003). In order to observe repeatable, sensitive results, being able to look at variability between cattle and within cattle tests for changes in feeding behavior may be the key to mitigating stress in cattle.

The focus of these studies was to examine the effects of different strains of *Saccharomyces cerevisiae* (live-yeast) on growth efficiency and feeding behavior responses of individual animals to better understand the mechanisms by which live-yeast supplementation aid animals in coping with stressful conditions.

History of Direct Fed Microbial

The use of **direct-fed microbial agents (DFM)** to enhance animal health and growth efficiency are of great interest to the beef industry. Supplementing cattle with DFM has been shown to improve growth and efficiency (Robinson, 2002). Although the mechanisms of action of DFM have yet to be fully explained, favorable responses to DFM may be related to the effects DFM have on ruminal environment through stabilization ruminal pH and fermentation. Recently, societal concerns regarding the use of antibiotics and growth stimulants in beef production systems has escalated, which has renewed interest in development of technology to prevent disease and(or) promote more judicious use of antibiotics for livestock production systems. Recent research suggests that DFM may improve immune system response to disease challenge (Finck et al., 2014).

The FDA defines DFM as naturally occurring live and viable organisms that are classified into three categories; *Bacillius*, lactic acid bacteria, and yeasts. *Bacillius* is a unique, gram positive rod that form spores that have the ability to become active vegetative cells when ingested by the animals. These spores are very stable and can withstand environmental conditions such as heat, moisture, and a range of pH. The second group is lactic acid bacteria, a gram-positive cocci or rods that produce lactic acid, which are antagonistic to pathogens. These bacteria can be somewhat heat sensitive and typically have to be included into the diet in a pelleted form. The final classification includes yeast products, which are eukaryotic microorganisms that are members of the fungus kingdom (ADM, 2015).

In newly received calves, cumulative stressors from weaning, transport, fasting, vaccination, castration, and dehorning may lead to a negative impact on performance and health. Fox (1988) evaluated the results from multiple studies that examined the efficacy of various DFM products fed to newly-weaned beef calves during the receiving period. Across studies, Fox (1988) found that DFM products improved ADG, DMI and F:G during the receiving period by 13.2, 2.5 and 6.3%, respectively, compared to control animals. Performance responses to use of DFM appear to be higher during the initial phase of the receiving period (Crawford et al., 1980; Hutcherson et al., 1980). Gill et al. (1987) found that feeding a DFM during the first 28-d of a receiving period improved ADG by 9.3% and feed efficiency by 9.5%, and reduced morbidity by 10.9%. However, not all studies have demonstrated favorable performance responses to feeding DFM (Kiesling and Lofgreen 1981; Krehbiel et al., 2001). Some of the inconsistent responses to DFM may be because these later studies focused on finishing steers fed high concentrate diets.

Research in finishing feedlot cattle has demonstrated that supplementation with lactate-producing or lactate-utilizing bacteria can improve feed efficiency and daily gain (Galyean et al., 2000, Rust et al., 2000a,b). In steers consuming a steam-flaked corn based diet, Swinney-Floyd et al. (1999) found that supplementation with a combination of *L. acidophilus 53545* and *P. freudenreichii* P-63 (lactate acid bacteria) improved feed efficiency by 16% when supplemented with *L. acidophilus* and 43% when supplemented with *P. freudenreichii*. During the first 10 d of the high-concentrate feeding period, daily gains were 0.93, 1.11, and 1.63 kg/d and F:G were 5.17, 5,32, and 4.50 for control, *P.*

freudenreichii, and the combination of *P. freudenreichii* and *l. acidophilus* treatments, respectively (Sinney-Floyd et al., 1999).

Direct fed microbial products have typically been more commonly used in the dairy cattle industry to due improvements ruminal digestion, DMI, and reduced body temperature (Piva et al., 1993; McGilliard and Stallings, 1998). Active dry yeasts can survive and remain metabolically active in the gut, especially in ruminant animals, and can exert probiotic effects by interacting with microbial species. Live yeast supplementation has been shown to have a beneficial effect on enhanced rumen microbial activity, lowered mean ruminal temperature, and less pronounced pH declines between feeding bouts. DeVries and Chevaux (2014) and Bach et al (2007) have suggested that the favorable effects of DFM on rumen fermentation have resulted in changes in feeding behavioral patterns, such as consumptions of more frequent and smaller-sized meals. The effects of DFM on improvements in rumen environment by stabilizing pH, may lead to improved feed efficiency of beef cattle (Erasmus et al., 2009).

Saccharomyces cerevisiae culture has been used as a feed additive in livestock production systems for many years, however, interest in the use of DFM has increased recently due to their potential as an alternative to the use of antimicrobial feed additives for growth promotion and efficiency. Therapeutic levels of antimicrobial feed additives are widely used in livestock production systems to treat diseased animals. Additionally, sub therapeutic doses of antimicrobials have been widely used to prevent disease and promote efficient growth of livestock (Barragry, 1994; American Veterinary Medical

Association, 2001). In response to consumer concerns about antimicrobial resistance, there has been renewed interest in the use of DFM as an alternative to use of sub-therapeutic use of antimicrobial feed additives to improve growth, feed efficiency and health status of livestock.

Yeast products based on *Saccharomyces cerevisiae* strains have been used with a range of success to enhance the ruminal environment, and promote the growth of favorable microbes. These yeast products have been shown to favorably increased DM intake and NDF digestion (Bach et al., 2007; Bach et al., 2009, Carro et al., 1992) in dairy cattle. Bach et al. (2007) reported that supplementation of active dry yeast improved ruminal pH and favorably impacted feeding behavior in lactating dairy cows. Cows supplemented with active dry yeast had a shorter interval between meals (3.32 h) than non-supplemented cows (4.03 h) indicating that they ate more frequent meals per day. Recent studies in beef cattle have also shown that supplementation with active dry yeast increases frequency of feeding events (Loncke et al., 2012). DeVries and Chevaux (2014) found that DMI, eating time, and eating rate were not affected by supplementation of dairy cattle with *Saccharomyces cerevisiae*, but that live-yeast supplementation improved meal patterning, including more frequent meals that tended to be smaller in size and occurred closer together.

Recent research has demonstrated that DFM may have a favorable effect on immune function. Carroll et al. (2010) found that beef calves previously supplemented with *Saccharomyces cerevisiae* had reduced inflammatory responses to lipopolysaccharide (LPS) challenge, suggesting improved immune response to disease.

Live-yeast supplementation resulted in reduced rectal temperature and peak cortisol responses to an LPS challenge, and increased white blood cells, lymphocytes, and neutrophil counts resulting in reduced morbidity rates (Carroll et al., 2010). These results suggest that supplementation with *Saccharomyces cerevisiae* may enhance immune function and improve disease resistance in calves at risk for disease during stressful conditions.

Subacute ruminal acidosis (SARA) is a metabolic disorder classified as episodes of low-rumen pH between 5.2 and 5.6 (Cooper and Klopfenstein, 1996). There is considerable variability in the clinical symptoms associated with SARA including anorexia, development of intermittent diarrhea, dehydration, liver abscesses and development of laminitis (Kleen et al., 2003). During SARA, endotoxins are released due to lysis of Gram negative bacteria, which can translocate to blood and lead to inflammatory responses. Gonzho et al. (2005) demonstrated that endotoxin concentrations increase substantially during periods of grain feeding compared with feeding hay. More research needs to be done to assess the effects of feeding DFM under different stages of production and stressful environmental conditions.

Weaning and Shipping Stress

In many cow-calf production operations, calves are abruptly weaned and subjected to multiple stressors from the loss of the dam and changes in the physical environment (Newberry and Swanson, 2008), which often increases the incidence of bovine respiratory disease.

Limited studies have examined at the effects of live-yeast in weanling calves. Dawson et al. (1990) examined the effects of *Saccharomyces cerevisiae* on newly-weaned calves fed high-roughage diet, and found that concentrations of cellulolytic microorganisms were 5 to 40 times greater in live-yeast fed steers than in control steers. These results suggest that the live-yeast supplementation stimulated the growth of cellulolytic microorganisms, leading to an improvement in forage digestibility (Dawson et al., 1990).

Matthew et al. (1998) examined the effects of *Saccharomyces cerevisiae* supplementation in early-weaned pigs, and found that live-yeast supplementation increased feed intake and tended to increase weight gains compared to controls. However, in starter pigs, Kornegay et al. (1995) found that yeast-culture supplementation had no effect on ADG or F:G ratio.

Transportation of beef cattle involves a series of handling and confinement situations, which can create unavoidable stressful conditions. In the U.S., cattle are often shipped distances that exceed 1000 km (Grandin, 2000). Chirase et al. (2004) conducted a study in beef calves to examine the effects of transportation stress on serum concentrations of oxidative stress biomarkers, and found that the stress-induced increases in these biomarkers was associated with increased incidences of BRD-related morbidity and mortality rates in beef calves.

Weaning and shipping stressors cause reductions in feed intake and disruptions in animal's ruminal environment. Feeding live-yeast prior to these stressors may help

stabilize rumen environments and mitigate impacts of stressors associated with weaning, and transportation stressors.

Adjusting to High Grain Diets

When cattle are moved into feedlots, and adapted onto high-grain diets to quickly, the disruption in the ruminal environment can affect the normal microbial environment and has the potential to lead to acidosis. A study conducted with cannulated sheep receiving an active dry yeast product showed that when being adapted to a high-concentrate diet, rumen pH was maintained at values more compatible with an efficient rumen function, as shown by higher fibrolytic activities in the rumen of the supplemented animals versus controls (Chaucheyras-Durand and Fonty, 2006). A similar result was observed in rumen-cannulated dairy cows fed *Saccharomyces cerevisiae* daily while fed a high-concentrate diet (William et al., 1991).

Bach et al. (2007) evaluated the effect of *Saccharomyces cerevisiae* on rumen pH in lactating dairy cows in loosely housed pens. As the grain concentration of the diet was increased to support the higher energy demands of the lactating cows, they observed that cows supplemented with live yeast had an increased average ruminal pH. The authors suggested that the higher ruminal pH may be related to the changes in eating behavior patterns, as live-yeast fed cows had a shorter meal interval (3.32 h) versus unsupplemented cows (4.32 h).

Heat Stress

Feedlot cattle in the U.S. often face adverse effects due to hot climate conditions in the summer (Mader et al., 1999b). High ambient temperatures, relative humidity, and

solar radiation coupled with low wind speed can cause increased heat loads, which can lead to poor performance and sometimes death (Mader et al., 1999b; Hubbard et al., 1999). Hahn (1995) showed that during hot environmental conditions, DMI is a function of core body temperature. When an animal's core body temperature exceeds an optimal level, feed intake will begin to decline at a rapid pace, and in some cases extreme core body temperatures will lead to death. In a study conducted with dairy cows, supplementation with live yeast was shown to increase DMI, productivity, and feed efficiency (Moallem, 2009). A study conducted by Schingoethe et al. (2004) with dairy cows found that supplementation by *Saccharomyces cerevisiae* during mid lactation had increased DMI and a better conversion of energy-corrected milk per kilogram of DM intake during times of heat stress. Bruno et al. (2009) found that feeding *Saccharomyces cerevisiae* to lactating cows did not affect DMI, but led to improvements in milk yields and milk components when cows were heat stressed. Results from these studies suggest that yeast-culture supplementation may improve feed efficiency of dairy cattle experiencing heat stress.

The economic losses associated with excessive heat load have been attributed to reduced feed intake and productivity, and in extreme cases, death (Hahn, 1995, Hahn and Mader, 1997a). The effects of excessive heat load can be exacerbated when combined with other stressors, such as when cattle are adapted to high-grain diets, leading to adverse effects on rumen and physiological functions (Brink et al., 1990).

Carcass Quality

Animals prior to harvest are often subjected to multiple stressors including loading and unloading, transportation, and commingling and crowding in large market pens, deprivation of food and water, and extreme temperature environments. These stressors have the potential to adversely affect behavioral and physiological responses, which in extreme circumstances, can contribute to the reduction in carcass and lean meat quality (Warriss, 1990). Pre-harvest nutrition or management strategies that reduce the impact of these stressors may improve meat quality and the economic value of carcasses.

Several studies have been conducted to examine the effects of DFM on carcass quality in beef cattle. Geng et al. (2015) recently evaluated different strains of *Saccharomyces cerevisiae* (Levucell SC and Diamond V XP) in bulls fed high-grain diets and found that live-yeast supplementation improved growth performance, marbling, yield grade, and beef tenderness. Additionally, live-yeast supplementation increased back-fat depth, which indicated favorable responses in fat metabolism. In contrast, Mir and Mir (1994) found that feeding *Saccharomyces cerevisiae* during the finishing period did not affect performance or carcass characteristics in Hereford steers. In Pelibuey lambs supplemented with *Saccharomyces cerevisiae*, Kawas et al. (2007) found that live-yeast supplementation did not impact performance, feed efficiency or hot carcass weight, marbling score, external fat, or longissimus muscle area.

Feeding Behavior

Traditionally, research focused on eating or feeding behavior was conducted with animals housed in tie stalls (Mulligan et al., 2002), or group pens with animals trained to

eat from individual feed bunks using Calan-gate feeders (Daniels et al., 2006). These feeders are designed in a way that allows a single animal to access a designated bunk while allowing the animal to be free from confinement in individual stalls. Feeding behavior patterns can also be measured using observational (e.g., video) methods, which are very labor intensive. These methods also may not accurately reflect the intake of cows housed in typical large group pens, where they often need to compete for access to feed (DeVries and von Keyserlingk, 2006; Huzzey et al., 2006). Additionally, capturing behavior data monitored by direct observation or time-lapse video recordings can be very labor intensive (Friend et al., 1977; Huzzey et al., 2005).

Recent advances in electronic feed intake systems have provided opportunities to examine factors that affect feeding behavior in larger populations of animals housed in group pens. An example of an automated feed intake measurement system is one manufactured by GrowSafe Systems Ltd. (Alberta, Canada). This system uses radio frequency identification (RFID) to individually record animal feed intake and feeding behavior. This system restricts access to feed bunk, such that only one animal can consume feed from a feed bunk at a given time in order to collect feed intake and feeding behavior traits on an individual-animal basis. Feeding behavior traits, such as frequency and duration of feeding events associated with feed consumption can be collected continuously, in a much less labor intensive manner.

Another behavioral trait that important to consider involves an animal's physical activity, such as frequency and duration of lying events and total distance traveled on a daily basis. Earlier studies that measured behavioral traits relied on visual observation

methods, which is not always accurate as the presence of the observer can sometimes alter an animal's behavioral responses (Gary et al., 1970). Moreover, visual observations methods are typically labor intensive, which limits the number of animals and observations that can be collected.

In recent years, advancements in accelerometer technology has become a reliable method to measure physical activity, behavior changes, and animal welfare (Endres and Barberg, 2006; Muller and Schrader, 2003; Trenel et al., 2009; Tolkamp et al., 2010). A number of recent studies have validated various types of activity monitors, and found them to provide accurate measurements of activity in dairy cows (Muller and Schrader, 2003; Nielsen et al., 2010), beef cows (Tolkamp et al., 2010), and dairy calves (Trenel et al., 2009).

The definition of a standing bout versus a lying bout has been defined in a variety of ways depending on the accelerometer device used. Using TinytagPlus data loggers (OnsetComp), O'Driscoll et al. (2009) defined lying bouts as those events with a minimum of 10 min of lying time in dairy cows that were either grazing pasture or fed in confined pens. Blackie et al. (2006) recorded lying behavior in dairy cows using the IceTag activity monitors, and disregarded any intervals less than 2 min while Trenel et al. (2009) proposed a lying period criteria of 24.8 s when measuring lying behavior in group-housed dairy calves. Tolkamp et al. (2010) recognized that there was a huge range of accepted time lengths to consider an event a lying bout. By analyzing short episode lengths, they determined a value of 4 min was an acceptable minimum duration for

defining a lying event, which eliminates possible misreads from the animal having sudden leg movements (Tolkamp et al., 2010)

Summary and Conclusion

In conclusion, feeding DFM, such as *Saccharomyces cerevisiae*, has been shown to improve overall rumen function by stabilizing rumen pH and fermentation, which can lead to improved performance and efficiency of feed utilization in animals, and improve disease resistance, especially during stressful environments. The objectives of this research were to examine the effects of different strains of *Saccharomyces cerevisiae* in newly-weaned stressed calves and in yearling steers fed in a heat-stress environment on growth efficiency and feeding behavioral responses.

CHAPTER II

EFFECTS OF *SACCHAROMYCES CEREVISIAE BOULDARII* (STRAIN I-1079) SUPPLEMENTATION DURING THE RECEIVING PERIOD ON GROWTH, EFFICIENCY, BEHAVIORAL AND HEALTH RESPONSES IN WEANLING BEEF HEIFERS

Introduction

Stressful conditions of beef calves can increase cost of production for producers including increased feed costs, decreased gains, increased cost of medical treatments, and in the worse cases death. Antimicrobials have been widely used to mitigate the effects of stress, but societal concerns about antimicrobial meat residues and bacteria resistance to drugs has prompted the industry to search for new strategies to reduce the impacts of stressful conditions on animals. The use of probiotic feed supplements to enhance animal health and growth efficiency are of a great interest to the beef industry, especially in newly weaned calves experiencing stress during transportation and commingling.

Live yeast products (i.e. *Saccharomyces cerevisiae*) are a type of direct-fed microbial (DFM) that has been widely used in the last 20 years. Several studies that have demonstrated that live-yeast may help stabilize rumen pH to mitigate acidosis, which has been shown to increase digestibility and reduce morbidity (Chaucheyras-Durand et al., 2008; Bach et al., 2007). DeVries and Chevaux (2014) also showed that live-yeast supplementation can lead to a shorter meal criterion (minimum inter-meal interval), and

more frequent smaller meals in cattle, which may be the result of stabilization of ruminal fermentation. This combination of outcomes in the ruminal environment and behavioral traits may lead to an improvement in feed efficiency in beef calves subjected to multiple stressors including abrupt weaning, transportation, commingling, and diet changes that are common in beef production systems.

Recent research has demonstrated that beef calves previously supplemented with *Saccharomyces cerevisiae* have reduced inflammatory response to lipopolysaccharide (LPS) challenge (Galvao et al., 2005). Zinn et al., (1999) showed that supplementation with live-yeast reduced morbidity by 48% and total sick days by 44% compared to control animals.

Additionally, the likelihood of differential responses to stress due to complex interaction of individual temperament, and environment may mask important outcomes in controlled experiments. Assessment of between-animal variation in responses may afford insight into effective strategies to mitigate stress. Therefore, the objectives of this study were to examine the effects of live yeast supplementation on feed intake, performance, and feeding behavior patterns in newly-weaned heifers, and to evaluate effects on the immunological responses in heifers, related to both stress mitigation and disease resistance.

Materials and Methods

Animals and Management

All animal care and use procedures were in accordance with the guidelines for use of Animals in Agriculture Teaching and Research as approved by the Texas A&M University AACUC (#2014-0194).

Seventy-two crossbred heifers (75% British, 25% *Bos indicus*) born and raised at the Texas A&M AgriLife McGregor Research Center (McGregor, TX) were used in this study. The initial BW and age of the heifers were 203 ± 22 kg and 213 ± 19 d, respectively. The heifers received a multivalent clostridial vaccine (Ultrachoice® 8, Zoetis) prior to the start of the study, but were not previously vaccinated for viral and bacterial respiratory pathogens. At weaning, heifers were weighed and vaccinated for infectious bovine rhinotracheitis, parainfluenza-3 virus, bovine viral diarrhea, bovine respiratory syncytial virus (Pyramid 5, Boehringer Ingelheim), and *Haemophilus somnis*, *Pasteurella multocida* (Express® 5-HS; Boehringer Ingelheim).The following day, heifers were shipped approximately 800 km, before being returned to the research center holding pens for the night. Heifers were then weighed and processed and placed in GrowSafe pens for the remainder of the study.

Treatment and Feed Sampling

Heifers were blocked by pre-weaning BW, and randomly assigned to 1 of 2 treatments (2 control pens; 2 live-yeast treatment pens, ProTernative®; provided by Lallemand Animal Nutrition). The diet (Table 2.1) contained a concentration of the live-yeast product that was formulated to target a consumption of 28 g/d/hd (10×10^9

cfu/hd/d). Heifers were placed in 1 of 4 pens (54 x 22 m), each equipped with 3 GrowSafe feed bunks and a water trough. There were no wind breaks or roof structures in the pens to protect heifers wind and rain during the study. Heifers were fed ad libitum once daily at approximately 0800 h, and feed bunks were cleaned weekly.

Diet samples were collected weekly and composited by weight at the end of the study. Moisture analysis was collected by drying in a forced air oven for 48 h at 105.0°C. Chemical analysis was completed by an independent laboratory (Cumberland Valley Analytical Services Inc., Hagerstown, MD).

Table 2.1. Ingredient and chemical composition of the experimental diet.

Item	
Ingredient (As-fed basis)	
Dry-rolled corn, %	27.5
Dried distillers grain, %	28.0
Chopped alfalfa, %	35.0
Molasses, %	5.0
Mineral Premix, %[1]	2.5
Treatment Premix, %[2]	2.0
Chemical Composition (Dry-matter basis)	
Dry matter, %	89.3
CP, %	16.5
NDF, %	33.2
ME, Mcal/kg	1.59

[1]Mineral Premix contained minimum 15.5.% Ca, 2800 ppm Zn, 1200 ppm Mn, 12 ppm Se, 14 ppm Co, 30 ppm I, 45.4 KIU/kg Vit-A, 2.3 KIU/kg Vit-D, 726 IU/kg Vit-E.
[2]Treatment premix contained dried distillers grain and limestone as carrier.

Data Collection

Heifers were re-vaccinated on day 28 of the study using the same product administered at weaning. During the first 56 d of the study, heifers were weighed and blood samples collected at 7-d intervals. Exit velocity were measured prior to shipping, and on days 0, 28, and 56 of the study as the time an animal transversed a distance of 2.44 m upon release from a squeeze chute. Temperature sensors (iButton devices, Maxim Integrated) were placed vaginally with an insert (CIDR; containing no hormones) to record temperature of 36 (9 per pen) of the 72 heifers during the first 14 d of the study. Additionally, accelerometer devices (HOBO Pendant G Data Logger; Onset) strapped onto the left hind leg of the same 36 heifers to collect physical activity data.

Feed intake and feeding behavior data were collected daily using the GrowSafe System (DAQ 6000E), which consists of feed bunks equipped with load bars to measure feed disappearance, and an antenna to record animal presence via detection of EID tags. Feed intake and feeding behavior data were omitted for the first 5 d of the study while heifers acclimated to eating from the GrowSafe bunks. From days 6 to 70 of the study, all data for 2 d (days 39 and 51) were deleted due to system failure (power outage, equipment malfunction). Feeding behavior and intake data were omitted from all analyses when the proportion of daily feed supply assigned to individual animals (average feed disappearance) was less than 95% (d 39 and 51). Average disappearance for the 63 d of good data was 98.6%. For this study, the parameter setting of 100 s was

used as recommended by Mendes et al. (2011). Feed intake and feeding behavior data was collected for the entire 70-d study.

Feeding behavior traits evaluated in this study included head-down (HD) duration and frequency and duration of bunk visit (BV) events recorded by the GrowSafe system. A BV event commenced when the EID of an animal was first detected, and ended when the time between consecutive EID recordings exceeded 100 s, was detected at another feed bunk, or when the EID of another animal was detected at the same feed bunk (Mendes et al., 2011). Bunk visit frequency was defined as the number of independent events recorded regardless of whether or not feed was consumed, and BV duration as the sum of the lengths of all BV events recorded during a 24-h period. HD duration was computed as the sum of the number of times the EID for an animal was detected each day multiplied by the scan rate of the GrowSafe® system (1.0 s). Bunk visit event data were clustered into meal events after meal criterion, defined as the longest non-feeding interval that is still part of a meal, was determined for each animal (Bailey et al., 2012). A Gaussian-Weibull distribution model was fitted to log-transformed non-feeding interval data, and the intercept of the two distributions used to define meal criterion (Yeates et al., 2001). Meal criterion was used to compute individual-animal meal data (meal frequency, meal duration, and meal size). Time to bunk (TTB) was computed daily as the interval length between time of feedtruck delivery within pen and each animal's first BV event.

Blood samples were collected via the jugular venipuncture in evacuated tubes (7mL) with no additive and placed on ice until possessed using a refrigerated centrifuge

4º. Serum samples were harvested following centrifugation at 7004 x g for 10 min, and stored at -20ºC for subsequent analysis of IBR titers at the Texas A&M Veterinary Medical Diagnostic Laboratory (Amarillo, TX).

Sickness Detection and Treatment

Heifers were visually assessed for clinical illness twice daily, and clinical scores (1 to 5) assigned for degree of respiratory insult, digestive insult, and lethargy (Table 2.2). Heifers with clinical scores (greater than or equal to 5) were removed from pen for further evaluation, and administered antimicrobial therapy (Micotil®; Elanco Animal Health) if rectal temperature was elevated (greater than or equal to 40 ºC). Heifers requiring a second treatment were administered Baytril® (Bayer).

Table 2.2. Clinical scoring system for visually assessment of clinical illness.

Score (0-5)	Respiratory insult	Digestive Insult	Lethargy score
0	No insult, No cough or nasal discharge	No insult, normal eating and drinking	No lethargy and normal posture
1	Slight nasal discharge and moderate cough	Mild or slight diarrhea with slight dehydration (<5%) and reduced eating	Mild anorexia or listlessness, depressed appearance
2	Moderate nasal discharge and moderate cough	Moderate diarrhea with 10% dehydration and < 50% of normal intake	Moderate lethargy and depression, slow to rise, anorectic
3	Moderate to severe viscous nasal discharge with cough	Moderate to severe diarrhea with >10% dehydration and < 10% normal intake	Recumbent or abnormal posture, largely depressed
4	Severe discharge with respiratory distress	Severe diarrhea and < 10% of normal intake	Prostrate, recumbent or abnormal
5	Dyspnea, tachypnea, marked respiratory distress	Severe diarrhea and not eating or drinking and dehydrated	Death

Statistical Analysis

Growth data was computed from linear regression of serial BW on day of study (PROC GLM, SAS). Feed efficiency was evaluated as F:G (DMI divided by ADG), and residual feed intake (RFI). Residual feed intake was derived from multiple linear regression of DMI on mid-test $BW^{0.75}$ and ADG. A linear mixed model (Mixed procedure, SAS Version 9.3) was used to analyze performance, DMI, and feeding behavior data with live-yeast treatment, temperature insert and the interaction included as fixed effects, and pen as a random effect. Physical activity and vaginal temperature data were analyzed using appropriate repeated-measures GLM procedure. Treatment differences in between-animal variation of dependent variables were assessed using Levene's test for equality of variances. Treatment differences in day-to-day variances of DMI were calculated as the variation in daily feed intake residuals for each day among animals within the same treatment. Daily DMI residuals were computed as the difference between each animal's mean DMI for a given period and each animal's daily DMI, and used to estimate each animal's day-to-day variance.

Results and Discussion

Sickness and IBR Titer Responses

During the first week of the study, 3 heifers were removed from the study due to failure to eat from the GrowSafe bunks, and 2 heifers were removed from the study due to lameness. During the study, 18 heifers (10 live-yeast heifers and 8 control heifers) exhibited clinical symptoms associated with BRD (mean morbidity scores were 3.20 and

3.25 respectively). Of these 18 heifers, 7 heifers (3 live-yeast heifers and 4 control heifers) had morbidity scores ≥ 5 and RT ≥ 40º C during the third wk of the study. All of the latter heifers responded to the first antimicrobial treatment. Thus, live-yeast treatment did not affect animal health status during the study.

Following the first vaccination for IBR, only 20% of heifers had IBR titers, whereas, 91% of the heifers responded to the second IBR vaccination. The IBR titer responses to first and second vaccinations were not affected by live-yeast treatment (Figure 2.1). These results suggest that the stressors associated with weaning and transportation may have impaired humoral immune responses to the first vaccination. Step et al. (2008) found that weaning and maternal separation were highly correlated with the incidence of undifferentiated BRD in beef calves. Griebel et al. (2014) found that weaning and transportation increased serum haptoglobin and blood leukocytes, supporting previous research that weaning and transportation stressors can contribute to the incidence and severity of BRD.

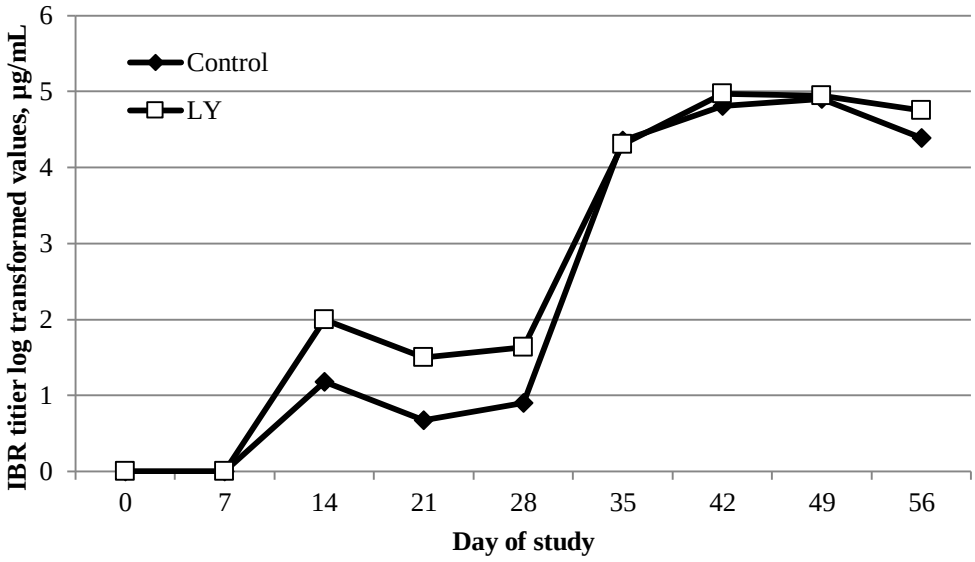

Figure 2.1. Effects of live-yeast (LY) supplementation on IBR titer response. Heifers were vaccinated on days 0 and 28 of the study. Standard error of 0.38.

As expected, DMI (4.25 kg/d) and ADG (0.15 kg/d) during the first 14-d was low due to abrupt weaning and shipping stress (Table 2.3). However live-yeast supplementation did not. affect performance or DMI during the first 14 d of the study. Although BV frequency and duration were not affected by live-yeast treatment, heifers supplemented with live-yeast consumed more frequent ($P < 0.05$) meals per day that tended ($P = 0.08$) to be smaller in size compared to control heifers. Time to bunk and HD duration were not affected by live yeast supplementation, but BV per meal was less ($P < 0.05$) for heifers consuming the live-yeast then those receiving the control diet.

Vaginal temperature and physical activity (standing bout frequency and duration) were not affected by live-yeast supplementation during the first 14-d of the study (Table 2.3). The effect of vaginal CIDR insert and its interaction with live-yeast treatment did not affect results during the first 14-d of the study or during entire study.

Table 2.3. Effects of live-yeast (LY) supplementation on performance, feed efficiency, and feeding behavior newly weaned heifers during the first 14-d of the study [1,2]

Item	Control	LY	SE	P-Value
No. of Heifers	32	35		
Performance and Efficiency traits				
Initial BW, kg	201.2	203.7	5.3	0.64
BW (d 14), kg	208.7	212.1	5.4	0.53
ADG, kg/d	0.151	0.133	0.113	0.87
DMI, kg/d	4.19	4.31	0.19	0.55
*Bunk visit (**BV**) traits*				
BV frequency, events/d	65.4	67.8	4.8	0.61
BV duration, min/d	98.6	96.2	8.7	0.78
Meal traits				
Meal criterion, min	9.47	7.80	2.77	0.55
Meal frequency, events/d	13.9	18.0	1.6	**0.011**
Meal duration (**MD**), min/d	189.3	175.8	15.5	0.39
Meal length, min/event	18.37	13.85	3.56	0.21
Meal size, kg/event	0.389	0.311	0.044	**0.083**
Eating rate, g/min	24.20	26.87	1.91	0.17
Intensity traits				
Time to bunk, min	42.17	47.91	6.45	0.38
Head down duration (**HD**), min/d	47.5	45.5	6.3	0.75
BV per meal, events/meal	5.46	4.27	0.57	**0.042**
HD:MD ratio	3.49	4.83	0.69	**0.055**
Temperature and Physical Activity [3]				
Average vaginal temperature, C	39.17	39.22	0.2	0.95
Standing duration, min/d	637.0	668.1	20.5	0.14
Standing length, min/event	47.0	44.9	4.8	0.66
Standing frequency, event/d	15.2	18.0	2.2	0.21

[1] Feed intake and behavior data collected from days 5 to 14

[2] Effect of CIDR insert and interaction with live-yeast treatment were not significant (P > 0.2).

[3] Temperament and physical activity (n = 17).

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During the first 28-d of the study, ADG tended ($P = 0.09$) to be higher in heifers supplemented with live-yeast when compared to control heifers (Table 2.4). Although DM intake was not affected by live-yeast supplementation, between-animal variance in DM intake was less ($P < 0.01$) in live-yeast supplemented heifers compared to control heifers (0.72 vs 1.03 kg/d) during the first 28-d. Similar to results during the first 14 d of the study, live-yeast supplemented heifers consumed almost 3 more ($P < 0.05$) meals per day that tended ($P < 0.10$) to be both shorter in length and smaller in size compared to control heifers. Meal duration and eating rate were not affected by live-yeast supplementation, however, live-yeast supplemented heifers had fewer ($P < 0.05$) BV events per meal then control heifers.

Table 2.4. Effects of live-yeast (LY) supplementation on performance, feed efficiency, and feeding behavior in newly weaned heifers during the first 28-d of the study [1,2]

Item	Control	LY	SE	P-Value
No. of Heifers	32	35		
Performance and Efficiency traits				
Initial BW, kg	201.2	203.7	5.3	0.64
BW (d 28), kg	214.8	220.9	3.9	0.25
ADG, kg/d	0.432	0.625	0.080	**0.086**
DMI, kg/d	5.27	5.43	0.22[3]	0.46
F:G ratio	7.80	8.86	4.56	0.87
Bunk visit (BV) traits				
BV frequency, events/d	79.5	78.3	4.2	0.77
BV duration, min/d	99.0	101.2	8.0	0.78
Meal traits				
Meal criterion, min	4.75	3.96	0.49	0.11
Meal frequency, events/d	15.8	18.7	1.3	**0.034**
Meal duration (MD), min/d	174.5	169.6	10.8	0.65
Meal length, min/event	13.10	10.73	1.21	**0.055**
Meal size, kg/event	0.422	0.363	0.034	**0.086**
Eating rate, g/min	31.46	33.18	1.53	0.26
Intensity traits				
Time to bunk, min	32.94	32.79	4.14	0.97
Head down duration (HD), min/d	53.6	52.2	6.2	0.83
BV per meal, events/meal	5.49	4.49	0.42	**0.020**
HD:MD ratio	4.50	5.36	0.62	0.17

[1] Feed intake and behavior data collected from days 5 to 28.

[2] Effect of CIDR insert and interaction with live-yeast treatment ($P > 0.2$).

[3] Between-animal variance ($P < 0.01$) using Levene test. (Control and live-yeast SD = 1.03 and 0.72 kg/d, respectively).

The results for the first 56-d of the study are presented in Table 2.5. The DMI and performance of the heifers were within the expected range given their age and the experimental diet that was fed (Table 2.5). Although live-yeast treatment tended to improve performance during the first 28 d, live-yeast supplementation did not affect performance or DMI during the first 56 d of the study.

During the first 56 d of the study, heifers supplemented with live-yeast consumed more ($P < 0.05$) frequent meals that were smaller ($P < 0.05$) in size and tended ($P = 0.08$) to be shorter in length. Treatment differences in between-animal variance were detected for DMI and RFI during the first 56-d of the study (Table 2.5). Between-animal variance was assessed in 14-d and 28-d increments for DMI over the course of the 56-d study. Treatment differences in between-animal DMI variance was not detected when 14-d interval were evaluated, but heifers supplemented with live-yeast had less between-animal DMI variance when 28-d interval data were evaluated. Live-yeast supplemented heifers had less ($P < 0.01$) between-animal variance in DMI (0.59 vs 0.92 kg/d) and RFI (0.73 vs 0.48 kg/d) compared to control heifers over the entire study. Additionally, day-to-day variance in DMI was less ($P < 0.01$) for live-yeast-supplemented heifers, but only during the third wk of the study (Table 2.6). Treatment difference in diurnal patterns of DMI were not detected during the first 56-d study (Figure 2.2) The results also show that heifers fed live-yeast may have greater impacts on performance and efficiency when initially supplemented with live-yeast, then over the long term.

In this study there was no effect on morbidity seen on live-yeast treatment, but due to the small number of animals that were observed as morbid, more research needs

to be done. Zinn et al. (1999) found that supplementing live-yeast in calves prior to shipping reduced morbidity by 28% and total sick days by 44%. Keyser et al. (2007) found that supplementation with *Saccharomyces cerevisiae* (Strain I-1079) decreased morbidity in ship-stressed heifers only in those heifers that also receiving an oral prophylactic antibiotic.

Feeding behavior responses to live-yeast supplementation in this study were comparable to results reported in other studies. DeVries and Chevaux (2014) found that supplementation with live yeast in dairy cows resulted in improvements in meal patterning, which included smaller and more frequent meals. Bach et al. (2007) found that live-yeast supplementation shortened meal criteria (11.5 vs 14.5 min) and reduced the interval between meals when compared with control dairy cows. However, Ferraretto et al. (2012) found no difference in meal patterning of dairy cows due to live-yeast supplementation. A potential contributing factor to this different response may be that Ferraretto et al. (2012) used a common meal criterion for all animals, whereas, in the current study and those reported by DeVries and Chevaux (2014) and Bach et al. (2007), meal criterion was computed for each individual animal based on frequency and duration of non-feeding intervals.

DeVries and Chevaux (2014) and Bach et al. (2007) also observed no treatment differences in DMI due to live-yeast supplementation. A meta-analysis study conducted by Leviton et al. (2008) found that supplementation with *Saccharomyces cerevisiae* and monensin had a positive effect on F:G and ADG compared to control animals. A meta-

analysis by de Ondarza et al (2010) found that live-yeast supplementation improved F:G by 3.5%, which likely was due to improved rumen function.

Table 2.5. Effects of live-yeast (LY) supplementation on performance, feed efficiency, and feeding behavior in newly weaned heifers during the first 56-d of the study [1,2]

Item	Control	LY	SE	P-Value
No. of Heifers	32	35		
Performance and Efficiency traits				
Initial BW, kg	201.2	203.7	5.3	0.64
BW (d 56), kg	247.9	251.8	6.1	0.52
ADG, kg/d	0.833	0.859	0.050	0.60
DMI, kg/d	6.58	6.57	0.19[3]	0.98
F:G ratio	8.21	8.21	0.54	0.99
RFI, kg/d	0.06	-0.02	0.11[4]	0.58
Bunk visit (BV) traits				
BV frequency, events/d	88.5	87.6	4.4	0.83
BV duration, min/d	105.5	107.7	7.4	0.77
Meal traits				
Meal criterion, min	5.02	4.48	0.50	0.28
Meal frequency, events/d	14.6	16.8	1.1	**0.042**
Meal duration (MD), min/d	191.0	188.0	8.8	0.74
Meal length, min/event	14.88	12.80	1.17	**0.080**
Meal size, kg/event	0.553	0.475	0.036	**0.038**
Eating rate, g/min	35.29	35.95	1.49	0.65
Intensity traits				
Time to bunk, min	27.6	31.4	3.3	0.26
Head down duration (HD), min/d	60.1	59.2	6.1	0.88
BV per meal, events/meal	6.40	5.52	0.44	**0.046**
HD:MD ratio	0.31	0.31	0.023	0.86

[1] Feed intake and behavior data collected from days 5 to 56

[2] Effect of CIDR insert and interaction with live-yeast treatment (P > 0.2).

[3] Between-animal variance (P < 0.01) using Levene test. (Control and live-yeast SD = 0.92 and 0.59 kg/d, respectively).

[4] Between-animal variance (P < 0.01) using Levene test. (Control and live-yeast SD = 0.73 and 0.48 kg/d, respectively).

Table 2.6. Effects of live-yeast (LY) supplementation on daily feed intake variation from days 7 to 56 of the study [1]

Item	Control	LY	SE	P-Value
Week of Study [2]				
2	2.09	2.04	0.27	0.85
3	4.15	2.90	0.47	**0.009**
4	2.15	2.37	0.39	0.57
5	2.42	2.34	0.27	0.78
6	2.72	2.35	0.44	0.40
7	1.81	1.94	0.31	0.67
8	2.50	2.24	0.40	0.53
Overall	5.35	5.30	0.39	0.88

[1]Feed intake variation competed as the difference between average feed intake for an animal and daily feed intake

[2]Week 1 of the study removed due to intake data not being included for the first 5 days of the trial

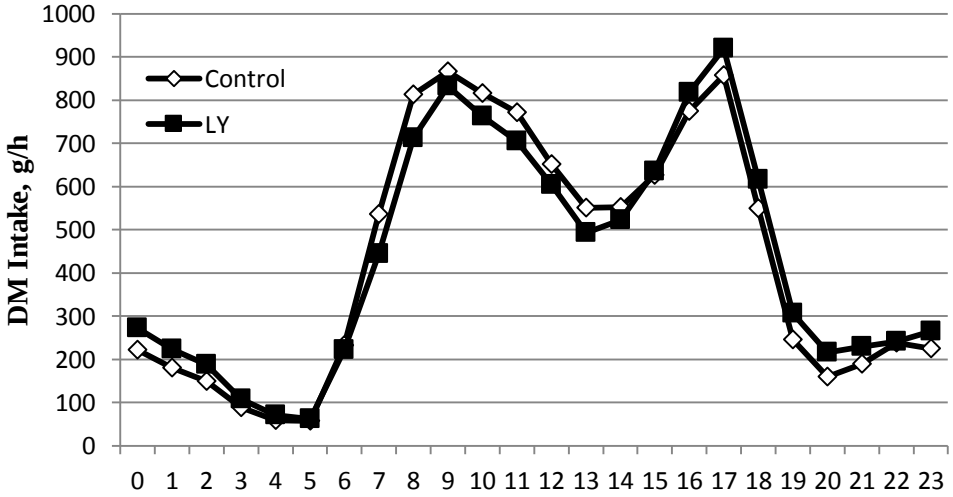

Figure 2.2. Effects of live-yeast (LY) supplementation on diurnal feed intake patterns (g DMI per h). Feed intake data collected from days 5 to 56 of the study. Animals were fed once daily at approximately 0800 h.

At the end of the 56-d study, performance and intake data were collected for an additional 14 d, with all heifers being fed the control diet. Average daily gain, DMI and F:G were not affected by live-yeast treatment (Table 2.7). In contrast to the first 56 d of the study, there were no treatment differences in meal traits or between-animal variance in DMI. Without live-yeast supplementation during the last 14-d of the study, the effects of live-yeast treatment on meal patterns became less apparent. Heifers that were supplemented with live yeast for the first 56-d tended ($P < 0.10$) to consume smaller more frequent meals, that were smaller ($P < 0.05$) in size (Table 2.7). Observations of the final 14 d demonstrated there was no effect due to live-yeast treatment when the yeast is no longer present (Table 2.8).

Pearson correlations were computed independent of treatment effects for the entire 70-d study (Table 2.9). As expected, ADG was positively correlated ($P < 0.01$) with DM intake (0.37), and negatively correlated ($P < 0.05$) with F:G (-0.89), and DMI was positively correlated ($P < 0.01$) with RFI (0.89). Bunk visit frequency and duration, meal duration, and HD duration are all positively correlated ($P < 0.05$) with DM intake and RFI (Table 2.10). Bunk visit duration and meal duration are also positively correlated ($P < 0.05$) with ADG.

Table 2.7. Effects of live-yeast (LY) supplementation on performance, feed efficiency, and feeding behavior in newly weaned heifers during the entire 70-d study [1,2]

Item	Control	LY	SE	P-Value
No. of Heifers	32	35		
Performance and Efficiency traits				
Initial BW, kg	204.3	206.6	5.3	0.65
Final BW, kg	252.7	257.3	6.1	0.46
ADG, kg/d	0.693	0.723	0.038	0.43
DM intake, kg/d	6.48	6.45	0.15	0.84
F:G ratio	9.82	9.35	0.58	0.43
RFI, kg/d	0.05	-0.05	0.13	0.50
*Bunk visit (**BV**) traits*				
BV frequency, events/d	87.18	85.59	4.29	0.71
BV duration, min/d	106.31	108.15	7.25	0.80
Meal traits				
Meal criterion, min	5.11	4.64	0.55	0.39
Meal frequency, events/d	14.16	16.34	0.98	**0.092**
Meal duration (**MD**), min/d	191.61	187.93	8.46	0.66
Meal length, min/event	15.34	13.14	2.20	**0.068**
Meal size, kg/event	0.587	0.509	0.038	**0.047**
Eating rate, g/min	38.71	39.73	2.61	0.70
Intensity traits				
Time to bunk, min	27.01	27.94	3.21	0.77
Head down duration (**HD**), min/d	59.95	58.84	6.24	0.86
BV per meal, events/meal	5.95	6.51	0.59	0.34
HD:MD ratio	0.35	0.34	0.03	0.80

[1] Feed intake and behavior data collected from days 5 to 70

[2] Effect of CIDR insert and interaction with live-yeast treatment ($P > 0.2$).

Table 2.8. Effects of live-yeast (LY) supplementation on performance, feed efficiency, and feeding behavior in newly weaned heifers during the last 14-d of the study [1,2]

Item	Control	LY	SE	P-Value
No. of Heifers	32	35		
Performance and Efficiency traits				
BW (d 56), kg	241.4	248.6	5.8	0.22
BW (d 70), kg	251.3	258.6	6.0	0.23
ADG, kg/d	1.25	1.24	0.06	0.93
DMI, kg/d	7.36	7.65	0.59	0.61
F:G ratio	6.11	6.59	0.63	0.45
Bunk visit (BV) traits				
BV frequency, events/d	88.14	84.34	4.78	0.43
BV duration, min/d	108.4	105.7	7.16	0.71
Meal traits				
Meal criterion, min	5.59	5.33	0.72	0.72
Meal frequency, events/d	198.0	191.6	8.50	0.46
Meal duration (MD), min/d	16.6	14.6	1.41	0.17
Meal length, min/event	13.69	15.00	0.91	0.16
Meal size, kg/event	0.712	0.673	0.05	0.37
Eating rate, g/min	33.35	35.82	2.38	0.30
Intensity traits				
Time to bunk, min	21.22	16.82	3.79	0.25
Head down duration (HD), min/d	70.3	66.8	6.79	0.61
BV per meal, events/meal	5.95	6.51	0.59	0.34
HD:MD ratio	0.35	0.34	0.03	0.80

[1] Feed intake and behavior data collected from days 5 to 70

[2] Effect of CIDR insert, and interaction with live-yeast treatment ($P > 0.2$).

Table 2.9. Pearson correlations between performance, and feed efficiency of newly weaned heifers during the 70-d study

Trait [1]	ADG	DMI	F:G	RFI
Initial BW	0.06	**0.28**	0.10	-0.00
ADG		**0.37**	**-0.89**	0.00
DMI			0.01	**0.89**
F:G				**0.34**

[1]Feed intake data were collected from day 5 – day 70 of this study.

Table 2.10. Pearson correlations between performance and feeding behavior traits of newly weaned heifers during the 70-d study

Trait[1]	IBW	ADG	DMI	F:G	RFI
*Bunk visit (**BV**) traits*					
BV frequency, events/d	-0.05	0.04	**0.32**	0.02	**0.35**
BV duration, min/d	0.07	**0.29**	**0.42**	-0.15	**0.34**
Meal traits[2]					
Meal criterion, min	-0.19	0.03	-0.18	-0.11	-0.15
Meal frequency, events/d	-0.12	-0.10	0.13	0.13	0.22
Meal duration (**MD**), min/d	-0.10	**0.26**	**0.33**	-0.20	**0.29**
Meal length, min/event	0.00	0.19	0.08	-0.18	-0.01
Meal size, kg/event	0.21	**0.37**	0.15	**-0.30**	-0.04
Eating rate, g/min	0.09	**-0.28**	0.04	**0.36**	0.13
Intensity traits					
Time to bunk, min	-0.02	-0.19	-0.06	0.14	0.01
Head down duration (**HD**), min/d	0.14	0.11	**0.37**	0.01	**0.33**
HD:MD ratio	**0.27**	-0.03	**-0.25**	-0.07	0.06
BV per meal, events/meal	0.06	0.07	-0.03	-0.09	0.25

[1]Feed intake and feeding behavior data were collected from day 5 – day 70 of this study.
[2]Meal data were derived from a 2-pool distribution model using Meal Criterion Software

Conclusion

Results suggest that live-yeast supplementation may favorably influence the rumen environment by animals consuming smaller more frequent meals that are shorter in length and by causing less variance in DM intake. In consuming meals in this pattern, DeVries and Chevaux (2014) found that cattle tended to ruminate longer, and have less periods of elevated rumen temperature. Further research is needed to more fully explore the rumen environment in heifers supplemented in live-yeast.

Also, IBR titer response suggests that the effect of stress due to weaning and transportation was present. Looking at the effects of feeding live-yeast prior to stresses, such as weaning and transportation, should be observed to see the effects on performance, efficiency, and meal traits in weanling heifers.

Finck et al. (2014) observed the effect of live-yeast supplementation on performance and health of newly weaned beef cattle. This study showed that supplementation with live-yeast increased ($P=0.05$) DMI when compared to control animals (6.02 vs 5.47 kg/d). Also results found that before receiving LPS challenge, the control calves had a higher ($P \leq 0.04$) when compared to live-yeast calves. These results indicate that observing immunological responses, such as white blood cells, lymphocytes, and neutrophils will also help with identifying if live-yeast supplementation improves immune system response to stress.

CHAPTER III

EFFECTS OF *SACCHAROMYCES CEREVISIAE* (STRAIN CNCM I-1077) AND A NOVEL LIVE-YEAST EXTRACT PRODUCT ON GROWTH, EFFICIENCY, FEEDING BEHAVIOR, PHYSICAL ACTIVITY AND CARCASS QUALITY OF YEARLING STEERS FED A HIGH-GRAIN DIET

Introduction

Direct fed microbial (DFM) have received renewed interest as a non-antibiotic strategy to improved animal health and performance responses in beef and dairy cattle. A meta-analysis done by de Ondarza (2010) examined the effects of *Saccharomyces cerevisiae* on performance and feed efficiency in dairy cattle, although the results have been not always been consistent due to differences in level of and source of yeast examined, composition of the ration, and the degree of animal stress (Williams et al., 1991). Bach et al. (2007) showed that supplementation with *Saccharomyces cerevisiae* in lactating dairy cattle not only improved ruminal pH, but also affected eating behavior. The cows supplemented with live yeast, had shorter intervals between meals. Loncke et al. (2012) found the beef calves supplemented with live yeast had improved F:G and an increase in meal frequency compared to controls. Bach et al. (2007) suggests that these changes in eating behavior due to live-yeast supplementation may be related to the live yeasts favorable effects on rumen fermentation (e.g., reduction in subclinical acidosis).

Research with dairy goats has shown that animals supplemented with live yeast sorted their ration more against fiber than non-supplemented goats (Desnoyers et al.,

2009b), suggesting that live-yeast supplemented goats were able to cope with a higher concentrate diets then control-fed goats due to better stability within the rumen.

The objective of the current study was to examine the effects of live-yeast supplementation on DMI, performance, feeding behavior, carcass quality and physical activity and rumen temperature of finishing steers fed a high-concentrate diet during summer months in hot climatic conditions. Additionally, this study sought to compare these performance responses to a novel new live-yeast product.

Materials and Methods

Animals and Management

All animal care and use procedures were in accordance with the guidelines for use of Animals in Agriculture Teaching and Research as approved by the Texas A&M University Institutional Animal Care and Use Committee (#2014-0194).

Seventy-seven crossbred beef steers (75% British, 25% *Bos indicus*) born and raised at the Texas A&M Agrilife McGregor Research Center (McGregor, TX) or the Beef Cattle Systems Research Center (College Station, TX) were used for this study (steers at both facilities had similar breed composition). The initial BW and age of the steers at the start of the trial were approximately 435 ± 27 kg and 433 ± 23 d.

Treatment and Feed Sampling

Steers were blocked by source location (McGregor vs College Station) and BW, and randomly assigned to 1 of 3 treatments (Control; live-yeast treatment, Levucell SC; and live yeast + extract, Levucell SC +yeast extract; provided by Lallemand Animal

Nutrition). A high-grain (dry-rolled corn) based diet (Table 3.1) contained a concentration of the live-yeast product that was formulated to target a consumption of 56 g/day/hd (10 x 10^9 cfu/hd/d), with inclusion rates adjusted at 14-d intervals as needed to maintain target consumptions rates throughout the study. During a 28-d adaptation period, all steers were stepped up onto the control diet containing the carrier premix, and acclimated to eating from GrowSafe feed bunks. Steers were placed into 1 of 6 pens with 2 pen replicates per treatment (Pen 1 = 14 x 23 m; Pen 2 = 23 x 29 m), each equipped with GrowSafe feed bunks (Pen 1 = 3, Pen 2 = 4) and a water trough. During this study, shade and bedding were not provided. Steers were fed once daily at approximately 0800 h, and feed bunks cleaned once a week.

Diet samples were collected weekly and composited by weight at the end of the study. Moisture analysis was collected by drying in a forced air oven for 48 h at 105.0°C. Chemical analysis was completed by an independent laboratory (Cumberland Valley Analytical Services Inc., Hagerstown, MD).

Table 3.1. Ingredient and chemical composition of the experimental diet.

Item	
Ingredient (As-fed basis)	
Dry-rolled corn, %	56.0
Dried distillers grain, %	24.0
Chopped alfalfa, %	10.0
Molasses, %	5.5
Mineral Premix, %[1]	2.5
Treatment Premix, %[2]	2.0
Chemical Composition (Dry-matter basis)	
Dry matter, %	89.3
CP, %	12.7
NDF, %	24.9
ME, Mcal/kg	2.84

[1]Mineral Premix contained minimum 15.5.% Ca, 2800 ppm Zn, 1200 ppm Mn, 12 ppm Se, 14 ppm Co, 30 ppm I, 45.4 KIU/kg Vit-A, 2.3 KIU/kg Vit-D, 726 IU/kg Vit-E.
[2]Treatment premix will contained dried distillers grain and limestone as carrier.

Data Collection

Steers were weighed at 14-d intervals during the 70-d study. Blood samples were collected at 14-d intervals during the 70-d study, and exit velocity measured on days 0, 28, 56, and 70 of the study. Exit velocity was measured as the time required for an animal to transverse a distance of 2.44 m upon release from the squeeze chute.

Bolus temperature sensors (BellaAg Systems, Loveland, CO) were placed in the rumen to record temperature of 30 (5 per pen) of the 72 steers during the study. The boluses were programmed to record rumen temperature at 15-min intervals, and data transmitted wirelessly to a base station located next to the data acquisition computer for the GrowSafe system. Additionally, accelerometer devices (HOBO Pendant G Data

Logger; Onset) were strapped to the left hind leg of the same 36 steers to collect physical activity data at 14-d alternating intervals during the 70-d study.

Feed intake and feeding behavior data were collected daily using the GrowSafe System (GrowSafe System Ltd, Arie, Alberta, Ca), which consists of feed bunks equipped with load bars to measure feed disappearance, and an antenna to record animal presence via detection of EID tags. Feed intake and feeding behavior data was omitted for days 0 to 7 for one pen and days 40 to 43 for another pen due to system failure (power outage, equipment malfunction). Feeding behavior and intake data were omitted from all analyses when the proportion of daily feed supply assigned to individual animals (average feed disappearance) was less than 95%. Average disappearance for the 70 d of good data was 97.4%. For this study, the parameter setting of 100 s was used as recommended by Mendes et al. (2011). Feed intake and feeding behavior data was collected for the entire 70-d study.

Feeding behavior traits evaluated in this study included head-down (HD) duration and frequency and duration of bunk visit (BV) events recorded by the GrowSafe system. A BV event commenced when the EID of an animal was first detected, and ended when the time between consecutive EID recordings exceeded 100 s, was detected at another feed bunk, or when the EID of another animal was detected at the same feed bunk (Mendes et al., 2011). Bunk visit frequency was defined as the number of independent events recorded regardless of whether or not feed was consumed, and BV duration as the sum of the lengths of all BV events recorded during a 24-h period. HD duration was computed as the sum of the number of times the EID for an

animal was detected each day multiplied by the scan rate of the GrowSafe® system (1.0 s). Bunk visit event data were clustered into meal events after meal criterion, defined as the longest non-feeding interval that is still part of a meal, was determined for each animal (Bailey et al., 2012). A Gaussian-Weibull distribution model was fitted to log-transformed non-feeding interval data, and the intercept of the two distributions used to define meal criterion (Yeates et al., 2001). Meal criterion was used to compute individual-animal meal data (meal frequency, meal duration, and meal size). Time to bunk (TTB) was computed daily as the interval length between time of feed truck delivery within pen and each animal's first BV event.

Blood samples were collected via the jugular venipuncture in evacuated tubes (7mL) with no additive and placed on ice until possessed using a refrigerated centrifuge 4º. Serum samples were harvested following centrifugation at 3000 rpm for 10 min, and stored at -20ºC.

Carcass Data Collection

At the end of the 70-d individual intake measurement trial, steers were maintained on their respective dietary treatments until harvest at an approximate low-choice quality grade endpoint, at Sam Kane Beef (Corpus Christi, TX). Animals were stunned via captive bolt pistol and exsanguinated. Liver and lungs were subjectively evaluated for signs of abscesses. On the day of harvest, individual hot carcass weights were recorded. Following a 48 h chill at -4°C, 12-13th rib fat thickness (BF), longissimus area (REA), kidney, pelvic, and heart fat (KPH) and marbling scores (MS) were collected by trained university personnel to determine quality and yield grade.

Sickness Detection and Treatment

Steers were visually assessed for clinical illness once daily, and clinical scores (1 to 5) assigned for degree of respiratory insult, digestive insult, and lethargy (Table 2.2). Steers with clinical scores ≥ 5 were removed from pen for further evaluation, and administered antimicrobial therapy (Micotil®; Elanco Animal Health) if rectal temperatures ≥ 40° C.

Statistical Analysis

Growth data was computed from linear regression of serial BW on day of study (PROC GLM, SAS). Feed efficiency was evaluated as F:G (DMI divided by ADG), and residual feed intake (RFI). Residual feed intake was derived from multiple linear regression of DMI on mid-test $BW^{0.75}$ and ADG. A linear mixed model (Mixed procedure, SAS Version 9.3) was used to analyze performance, DMI, carcass traits and feeding behavior data with live-yeast treatment, temperature insert and the interaction included as fixed effects, and pen as a random effect. Physical activity and rumen temperature data were analyzed using appropriate repeated-measures GLM procedure. Treatment differences in between-animal variation of dependent variables were assessed using Levene's test for equality of variances. Treatment differences in day-to-day variances of dependent variables is calculated as the variation in daily feed intake residuals for each day among individually fed animals within the same treatment. In order to find intake residuals, the difference between the average daily dry matter intake of each day and each individual's daily dry matter intake. The sample variance is then calculated by using the intake residuals for each day.

In order to assess time series analysis of the physical activity data, a repeated measures mixed model was used. Various covariance structures were tested and the one with the minimum AICC was used. This structure was then used to test the fixed effects of yeast, day, and their interaction while using pen as a random effect. Day was repeated on the subject of animal.

Results and Discussion

Sickness Response

Only 4 steers were treated for clinical symptoms of BRD, and all responded to the first antimicrobial therapy. Live-yeast supplementation did not affect animal health status in this study.

Initial 28-d of the Study

Live-yeast treatment did not affect performance, DMI or feed efficiency during the first 28 d of the study. DM intake (14.2 kg/d) and ADG (1.70 kg/d) during the first 28 d on a high grain concentrate diet (Table 3.2) were as expected.

During the first 28-d of the feeding study, steers supplemented with live yeast approached the feed bunks 29% quicker ($P < 0.001$) upon feed-truck delivery compared to control steers. Although BV frequency was not affected by live-yeast treatment, BV duration and HD duration were 22 and 46% greater ($P < 0.01$) in live-yeast supplemented steers compared to control steers. Meal criterion and thus meal frequency was not affected by live-yeast supplementation. However, live-yeast supplementation increased ($P < 0.05$) total meal duration by 9%. Because DMI was not affected by live-

yeast treatment, meal eating rates was 6% slower ($P < 0.05$) for live-yeast compared to control steers. Similar to the live-yeast treatment, steers supplemented with live-yeast + extract had similar performance, DMI and F:G as control steers. The feeding behavior responses to live-yeast + extract supplementation did not differ from control steers.

Table 3.2. Effects of live-yeast (LY) supplementation on performance, feed efficiency, and feeding behavior in finishing steers during the first 28-d of the study [1,2]

	Treatment				
Item	Control	LY	LY + Extract	SE	P-Value
No. of Steers	24	24	24		
Performance and Efficiency traits					
Initial BW, kg	437.3	444.8	437.5	5.9	0.69
BW (day 28), kg	482.0	491.4	489.2	6.8	0.74
ADG, kg/d	1.59	1.67	1.85	0.13	0.35
DMI, kg/d	13.70	14.19	14.66	0.43	0.31
F:G ratio	7.62	9.33	9.93	1.20	0.42
*Bunk visit (**BV**) traits*					
BV frequency, events/d	41.3	40.8	41.3	2.0	0.96
BV duration, min/d	72.4[a]	88.4[b]	73.0[a]	4.1	**0.004**
Meal traits					
Meal criterion, min	7.00	8.06	6.25	0.74	0.17
Meal frequency, events/d	9.0	8.9	9.2	0.5	0.77
Meal duration (**MD**), min/d	131.2[a]	143.2[b]	124.2[a]	5.9	**0.027**
Meal length, min/event	15.80	17.75	15.14	1.25	0.17
Meal size, kg/event	1.46	1.60	1.56	0.09	0.21
Eating rate, g/min	110.5[a]	104.1[b]	120.9[a]	5.71	**0.020**
Intensity traits					
Time to bunk, min	79.0[a]	53.4[b]	72.1[a]	5.11	**<0.001**
Head down duration (**HD**), min/d	30.1[a]	43.8[b]	30.9[a]	3.4	**0.006**
BV per meal, events/meal	4.83	4.81	4.75	0.33	0.95
HD:MD ratio	2.16	2.58	2.22	0.23	0.63

[1] Feed intake and behavior data collected from days 0 to 28

[2] Effect of HOBO, and interaction with live-yeast treatment were not significant ($P > 0.25$).

Comparison of Traits for the 70 d Study

Performance and feed efficiency were not affected by LY treatment (Table 3.3). However, F:G was numerically 9.7% lower, and RFI 0.53 kg/d numerically less in live-yeast-supplemented steers compared to control steers. The ADG and feed efficiency of steers supplemented with live-yeast + Extract were similar to control steers. Evidence for treatment differences in between-animal variation in performance, feed efficiency and feeding behavior were not detected in this study. Additionally, live-yeast treatment did not affect diurnal feed intake patterns (Figure 3.1), or day-to-day variance in DMI.

Frequency of BV events was not affected by live-yeast treatment, but the duration of BV events and HD duration were 27 and 48% longer ($P < 0.01$), respectively, in live-yeast supplemented steers than controls steers. Steers supplemented with live yeast tended ($P < 0.10$) to have longer meal criterion then control steers, with steers receiving the live-yeast + extract treatment being intermediate. However, meal frequency was not affected by either live-yeast treatment.

Over the course of the entire 70-d study, live-yeast supplemented steers consumed meals that were 29% longer ($P < 0.05$) in duration and tended ($P < 0.10$) to be 17% larger in size compared to control steers. However, meal eating rate was 22% slower ($P < 0.001$) for live-yeast compared to control steers. Steers supplemented with live-yeast approached the feed bunks 35% sooner ($P < 0.05$) after feed-truck delivery than control steers. Steers supplemented with live-yeast + yeast extract tended ($P = 0.07$) to eat larger meals, at a slow rate ($P < 0.05$), but were of a moderate length when

compared to the other two treatments. In general, meal patterns of steers supplemented with live-yeast + extract were similar to control steers.

Gonzalez et al. (2011) concluded that cattle consuming feed at slower rates will likely spend more time ruminating and thus produce more saliva, which aids in the stabilization of rumen pH. Beauchemin et al. (2008) reported that cattle diet diets containing lower proportions of forage will eat at faster rates, spending less time salivating, and typically consuming larger meals. These research findings suggests that the effects of live-yeast supplementation on meal patterns may have favorably affected ruminal fermentation in this study.

As shown in previous studies, DMI was positively correlated ($P < 0.05$) with ADG (0.64; Table 3.4). ADG was positively correlated ($P < 0.05$) with meal criterion, duration, length, and size, while F:G was negatively correlated ($P < 0.05$) with all of these meal traits (Table 3.5). Eating rate was seen to be positively correlated ($P < 0.05$) with DM intake, F:G and RFI, but negatively correlated ($P < 0.05$) with ADG.

Table 3.3. Effects of live-yeast (LY) supplementation on performance, feed efficiency, and feeding behavior in finishing steers during the entire 70-d of the study [1,2]

	Treatment				
Item	Control	LY	LY + Extract	SE	P-Value
No. of Steers	24	24	24		
Performance and Efficiency traits					
Initial BW, kg	444.2	447.0	443.3	6.11	0.91
BW (day 70), kg	550.5	557.9	551.5	7.74	0.77
ADG, kg/d	1.52	1.59	1.55	0.05	0.64
DMI, kg/d	12.03	11.45	11.99	0.32	0.15
F:G ratio	8.15	7.36	8.00	0.31	0.17
RFI, kg/d	0.18	-0.35	0.17	0.22	0.17
*Bunk visit (**BV**) traits*					
BV frequency, events/d	39.3	38.1	37.6	1.6	0.75
BV duration, min/d	70.4[a]	89.4[b]	73.4[a]	3.8	**0.001**
Meal traits					
Meal criterion, min	7.51[a]	10.31[b]	8.71[ab]	0.75	**0.070**
Meal frequency, events/d	9.1	8.2	8.1	0.4	0.20
Meal duration (**MD**), min/d	125.2[a]	147.8[b]	124.8[a]	5.3	**0.004**
Meal length, min/event	15.40[a]	19.81[b]	17.01[ab]	1.20	**0.037**
Meal size, kg/event	1.50[a]	1.76[b]	1.78[b]	0.09	**0.065**
Eating rate, g/min	102.1[a]	79.9[b]	98.8[a]	4.37	**0.001**
Intensity traits					
Time to bunk, min	77.5[a]	50.3[b]	71.7[a]	4.81	**<0.001**
Head down duration (**HD**), min/d	30.0[a]	44.4[b]	30.7[a]	3.5	**0.007**
BV per meal, events/meal	5.28	4.81	4.64	0.66	0.46
HD:MD ratio	2.18	2.29	1.96	0.22	0.57

[1] Feed intake and behavior data collected from days 0 to 70

[2] Effect of HOBO, and interaction with live-yeast treatment were not significant (P > 0.25).

Table 3.4. Pearson correlations between performance and feed efficiency for finishing steers during the entire 70-d study

Trait	ADG	DMI	F:G	RFI
Initial BW	**0.25**	0.14	-0.16	-0.00
ADG		**0.64**	**-0.86**	-0.00
DMI			**0.58**	**0.97**
F:G				**0.45**

Table 3.5. Pearson correlations between performance and feeding behavior traits of finishing steers during the entire 70-d study

Trait	IBW	ADG	DMI	F:G	RFI
*Bunk visit (**BV**) traits*					
BV frequency, events/d	0.07	0.07	0.09	0.01	0.08
BV duration, min/d	-0.02	**0.32**	**-0.29**	**-0.39**	**-0.22**
Meal traits					
Meal criterion, min	0.04	**0.32**	-0.14	**-0.31**	-0.08
Meal frequency, events/d	-0.16	**-0.32**	-0.06	**0.21**	-0.10
Meal duration (**MD**), min/d	0.05	**0.41**	**-0.25**	**-0.43**	-0.19
Meal length, min/event	0.10	**0.43**	-0.09	**-0.37**	0.09
Meal size, kg/event	0.33	**0.51**	0.05	**-0.36**	0.03
Eating rate, g/min	-0.00	**-0.41**	**0.54**	**0.58**	**0.48**
Intensity traits					
Time to bunk, min	-0.07	**-0.24**	0.09	**0.25**	0.06
Head down duration (**HD**), min/d	-0.04	**0.31**	**-0.24**	**-0.36**	-0.18
HD:MD ratio	-0.17	-0.06	-0.12	-0.02	-0.12
BV per meal, events/meal	-0.12	**-0.27**	-0.08	0.16	-0.10

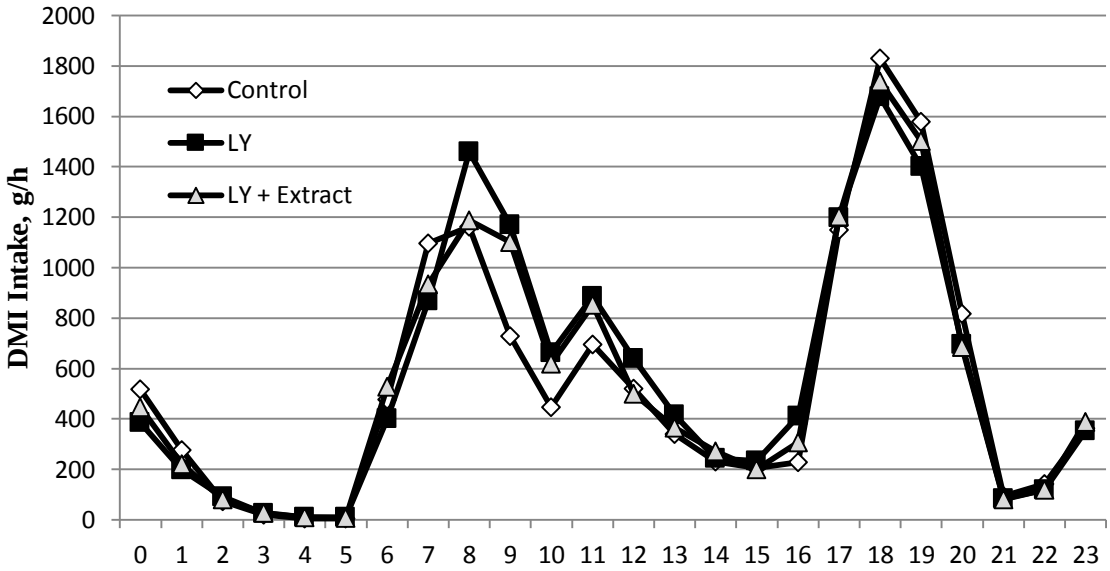

Figure 3.1. Effects of live-yeast (LY) on diurnal feed intake patterns (g DMI per h) for the entire 70-d study. Steers were fed at approximately 0800 h each day.

Carcass Data

Steers remained on feed for a total of 96 d prior to harvest. The live-yeast treatments did not affect any of the carcass traits measured in this study. Liver and lung scores obtained at the time of harvest were not affected by live-yeast treatment. The average incidences of liver and lung lesions were 33.3 and 26.4%, respectively. The average hot carcass weight and dressing percentage were 362.1 kg and 60.6%, respectively (Table 3.6) Steers had an average yield grade of 3.31 and an average quality grade of low choice. Although live-yeast supplementation did not affect backfat depth, steers supplemented with live yeast had a 12.1% higher backfat depth compared with other treatments.

Table 3.6. Effects of live-yeast (LY) supplementation on carcass traits for finishing steers

	Treatment				
Item	Control	LY	LY + Extract	SE	P-Value
No. of Steers	24	24	24		
Hot carcass weight, kg	360.8	365.4	360.0	5.29	0.74
Backfat depth, cm	0.610	0.711	0.658	0.04	0.16
LMA, cm^2	13.44	13.10	13.09	0.22	0.46
Kidney, pelvic and heart fat, %	2.0	2.0	2.0	0.00	1.00
Yield grade	3.20	3.31	3.43	0.13	0.10
Marbling score	Sm70	Sm10	Sm10	0.12	0.99
Quality grade	CH^-	CH^-	CH^-	0.40	0.92
Average L* color	44.35	44.54	44.19	0.38	0.81
Average a* color	17.32	17.32	17.68	0.45	0.81
Average b* color	8.98	8.95	8.72	0.24	0.70
Average pH	5.62	5.61	5.64	0.01	0.41

Temperature and Physical Activity Data

Ten steers from each treatment group, 5 from each pen, were selected at random to have a rumen temperature and physical activity monitored. Average rumen temperature and overall physical activity was also not affected by supplementation with live-yeast. Average rumen temperature was 39.7 ºC for the steers (Table 3.7). Physical activity was collected in 14 day increments from days 0-14, days 28-42, and days 56-70. Average standing length and frequency was 58.6 min/event and 41.6 event/d, respectively.

During the first 14-d of yeast supplementation, steers supplemented with live-yeast tended ($P = 0.07$) to spend more time standing then the steers fed the control and the live-yeast + extract diets. Physical activity was not affected by time during the study, or time x treatment interaction. Live-yeast supplemented steers had 16.8% fewer ($P < 0.05$) standing bouts compared to control steers. Munksgaard and Simonsen (1996) reported that increased interruptions in the resting behavior of animals can induce changes in the function of the HPA-axis, suggesting that the animals may be more prone to stress.

Table 3.7. Effects of live-yeast (LY) supplementation on rumen temperature and physical activity for the entire 70-d of the study [1,2]

	Treatment				
Item	Control	LY	LY + Extract	SE	P-Value
No. of Steers	10	10	10		
Rumen Temperature[1]					
Average, ºC	39.67	39.64	39.65	0.09	0.97
Physical Activity					
Overall trial average[2]					
Standing duration, min/d	705.96	715.70	713.70	19.01	0.93
Standing length, min/event	51.23	61.95	62.59	5.94	0.32
Standing frequency, event/d	15.76	13.10	12.72	1.47	0.30
Day 0 - day 14 average					
Standing duration, min/d	675.1	701.7	683.2	18.70	0.59
Standing length, min/event	44.80[a]	61.04[b]	55.04[a]	0.80	**0.073**
Standing frequency, event/d	15.71[a]	12.50[b]	13.68[ab]	4.78	**0.030**
Day 28 – day 42 average					
Standing duration, min/d	667.0	741.5	748.4	45.74	0.41
Standing length, min/event	53.29	66.13	68.14	1.39	0.30
Standing frequency, event/d	11.97	12.87	12.23	7.01	0.89
Day 56 – day 70 average					
Standing duration, min/d	687.2	640.4	709.5	47.27	0.56
Standing length, min/event	48.98	51.40	64.54	2.77	0.22
Standing frequency, event/d	18.63	12.96	12.24	6.56	0.24

[1] Adjusted to 3 sigma

[2] Chose Toeplitz based on minimum AICC. No significant interaction found.

Conclusion

Results from this study suggest that live-yeast supplementation may have favorably affected rumen environment. Numerically, steers supplemented with live-yeast had 9.7% more favorable F:G compared to control steers. Moreover, live-yeast supplemented steers spent 36% more time visiting the bunk each day when compared to control steers. The quicker feed bunk attendance following feed-truck delivery and reduced standing-bout frequency of live-yeast supplemented steers suggests these steers may have had better overall comfort compared with control steers. The strain of *Saccharomyces cerevisiae* used in this study has been shown to control rumen pH by favoring the competition between lactic acid utilizing bacteria and lactic acid producers, thereby reducing lactic acid accumulation in the rumen. Thus, live-yeast supplementation may have produced a more favorable rumen environment to foster enhanced rumen fermentation. Results suggest that further research is warranted to examine the effects of live-yeast supplementation on the relationships between meal patterns in cattle relative to optimal rumen fermentation.

Additionally, further research should be conducted to assess the effects of diet or heat-stress conditions on responses to supplementation with live yeast. Dawson (1990) reported that *Saccharomyces cerevisiae* supplementation increased cellulolytic activity in receiving calves by more than 15%. The diets used in Dawson (1990) study contained 77.5% ground forage, suggesting more cellulose available in the diet. Bach et al. (2007) found that rumen pH stabilization due to live-yeast supplementation was favorably associated with changes in meal patterns in dairy cattle fed diets containing high

concentrations of silage and hay. DeVries and Chevaux (2014) reported similar results in dairy cattle fed a diet containing more than 50% silage and hay. Collectively, comparing results from these studies to those found in the current study suggest that animal responses to live-yeast supplementation is likely influenced by type of diet.

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