THE EFFECTS OF A SUPPLEMENTAL PROBIOTIC-PREBIOTIC ON PERFORMANCE AND CARCASS CHARACTERISTICS OF NEWLY RECEIVED FEEDLOT CATTLE

by

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ABSTRACT

Two hundred and fifty-eight (average BW = 250 ± 11.4 kg) crossbred steers were received at the Texas A&M AgriLife Research Feedlot in Bushland, TX. Steers (n = 240) were stratified by average initial BW (d-1, d-0) and allocated to 1 of 2 BW blocks in a randomized complete block design. Steers were offered 1 of 3 dietary treatments. The control treatment (CON) received a pellet without probiotic-prebiotic blend (P-PB). Treatment 2 received a pellet with P-PB from d 0 to 21 followed by the CON pellet from d 22 to 42 (P-PB21). Treatment 3 received the P-PB pellet from d 0 to 42 (P-PB42). Following the 42-d receiving period, the treatment pellets were removed and replaced with steam-flaked corn (SFC) for the remainder of the finishing period. If dry-matter intake (DMI) was < 6.35 kg/steer/d, the P-PB pellet was included at 8.75% of the diet. If DMI was ≥ 6.35 kg/steer/d, the P-PB pellet was included at 6.25% of the diet. Steer BW was measured on d 21 and d 42 of the feeding period. Continuous data were analyzed using the MIXED procedure of SAS, categorical data were analyzed using the GLIMMIX procedure. Pen was considered the experimental unit, block a random effect, and treatment a fixed effect. No treatment effects were observed from d 0 to d 42 for BW ($P \geq 0.91$), average daily gain (ADG; $P = 0.97$), feed efficiency ($P = 0.99$), or dry matter intake (DMI; $P = 0.95$). No treatment differences were observed for percent morbidity or mortality ($P \geq 0.38$) from d 0 to 42. Supplemented P-PB did not impact longissimus area (LM), fat thickness, marbling score, USDA Quality or Yield grade ($P \geq 0.24$), while

dressing percent (DP; $P \leq 0.05$) and hot carcass weight (HCW; $P = 0.09$) were greatest for CON. While results remained similar between treatments, there were no negative effects on cattle health and performance during the receiving period.

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REVIEW OF LITERATURE

Direct Fed Microbials

History

Direct fed microbials (DFM) have been available for decades with a long and interesting history. Direct fed microbials are defined as a source of live, naturally occurring microorganisms by the U.S. Food and Drug Administration (FDA) and the Association of American Feed Control Officials (AAFCO, 1999). Many times, DFMs and probiotics have been considered to be one in the same. However, probiotics are defined as a live microbial feed supplement, which beneficially affects the host animal by improving its intestinal microbial balance (Fuller, 1989).

In 1908, Metchnikoff published *The Prolongation of Life*, in which he proposed that ingesting lactobacilli that are capable of surviving in the intestines may increase the longevity of human life (Gilliland, 1989; Yoon and Stern, 1995). Metchnikoff suggested this after studying the longevity of the Bulgarians who consumed fermented milk products which contained lactobacilli, preventing disease caused by enteropathogens (Yoon and Stern, 1995; Krehbiel et al., 2003). Due to his research, the efficacy of *Lactobacillus* species was highly studied during the 1920s and reached its peak during the 1930s (Stern and Storrs, 1975). Manneheim (1951) reported that antibiotics became popular after World War II, however, antibiotic diarrhea and related side effects were due to the antibiotics destroying both pathogenic and commensal bacteria in the

gastrointestinal tract (GIT). This led to *acidophilus* therapy to restore normal intestinal microflora (Krehbiel et al., 2003). Since then, research surrounding bacterial DFMs and probiotics mode of action and effects on animals and humans became more common.

Yeast supplementation has a rich history that starts with Eckles and Williams (1925) when they reported the use of yeast as a supplement for lactating dairy cows. Carter and Phillips (1944) and Steckley et al. (1979) observed that brewers yeast could be successfully used as a protein source in ruminant diets. During the 1940's and 1950's, the application of yeast in dairy cattle diets were more extensively studied. Beeson and Perry (1952) reported that ADG increased by 6% in steers fed 8 g/d of active dried yeast. Two years later, Renz (1954) compared levels of yeast supplementation in dairy cattle and reported that milk yield was increased by 1.1 kg/d when fed 50 g/d of an active yeast culture. Ruf et al. (1953) and Leatherwood et al. (1960) suggested that yeast may alter ruminal fermentation and increase cellulose digestion by ruminal microbes. Over the years, the use of fungal cultures has gained more attention as they have the potential to increase the health and productivity of animals.

Many products have been developed based on research conducted during the past century. These products have been designed to improve the health and productivity of livestock, enhance gut function, and improve feed efficiency and performance. Due to societal concerns over antimicrobial resistance among humans, interest in the effects and use of DFMs has significantly increased in the livestock industry. However, it wasn't until the mid-1990's that the effect that DFMs have on performance and health, along with the mode of action was evaluated extensively in livestock (Yoon and Stern, 1995).

Classification

Direct fed microbials can be classified as two types: lactate utilizing or lactate producing bacteria. Most studies test bacterial DFMs, but others have also evaluated different types of yeasts and molds. There are currently at least 42 individual species of microorganisms approved for use as DFMs (Krehbiel et al., 2003; Buntyn et al., 2016). All species of DFM microorganisms are regulated under the generally recognized as safe (GRAS) standards by the FDA. Direct fed microbials all have a common unit of measurement known as a colony forming unit (cfu). A colony forming unit is a cluster of live, viable cells within a culture of a specific bacterium.

Today, DFM products are constantly tested and screened for survivability and hardiness by growing them in a multitude of cultures. Direct fed microbials must be heat-stable and able to withstand harsh conditions once inside the animal.

Mode of action: bacterial DFM

For many years, the mode of action of DFMs has been considered complex and not well understood. Direct fed microbials have a vast array of indirect mechanisms of actions due to the diversity of strains utilized, feeding strategy implemented, forage-to-concentrate ratio in the diet, and physical condition or environment of the cattle (Wallace, 1994; Lehloenya et al., 2008). However, in order for the DFM to be efficacious, certain biological conditions must be met (Wilson and Krehbiel, 2012). In order for the DFM to survive and be effective within the rumen or gut, the DFM must be non-pathogenic, specific to the host and a stable organism (Holzapfel et al., 1998). The specific mechanism of action for any probiotic or DFM can vary from specie to specie. Some of

the primary mechanisms of actions suggested for probiotics or DFM include: the release of antimicrobial proteins, such as bacteriocins that hydrolyse bacterial toxins, competitive exclusion of pathogenic bacteria, production of nutrients and growth factors to stimulate desirable ruminal microorganisms, stimulation of the immune response system, detoxification of certain inhibitory compounds (amines or nitrates), and produce and increase enzyme activity (Fuller, 1989; Salminen et al., 1996; Holzapfel et al., 1998; Krehbiel et al., 2003; Beauchemin et al., 2006; Chaucheyras-Durand et al., 2008; Chaucheyras-Durand and Durand, 2009).

Most of the listed mechanisms influence the microbial population within the rumen and GIT. Competitive attachment or exclusion of pathogenic bacteria is critical to not only the health of the animal but also contributes to the overall performance during their time on feed (Krehbiel et al., 2003; Wilson and Krehbiel, 2012). The DFM competes with pathogenic bacteria for space within the intestinal lining. The more space the DFM takes up, the less the pathogen has to adhere and begin colonization, thus could help lead to improved animal performance (Beauchemin et al., 2006). Salminen et al. (1996) believed that attachment of the DFM supported proliferation and reduced peristaltic removal of organisms. Holzapfel et al. (1998) hypothesized that adhesion was mediated nonspecifically by physicochemical factors, or specifically by adhesive bacterial surface molecules. Muralidhara et al. (1977) supports Salminen et al. (1996) hypothesis as they observed a greater amount of *Lactobacilli* in intestinal tissue collected from piglets dosed with *L. lactis* compared to the number of *E. coli* within the tissue. Abu-Tarboush et al. (1996) findings also support this mechanism of action as the bacteria used, *L. acidophilus* 27SC was found adhered to the GIT in young calves. Elam et al.

(2003) fed different strains of *L. acidophilus* and one strain of *Propionibacterium freudenreichii* to cattle and measured the effects of these strains on the thickness of the lamina propria. Their results indicated that steers fed a form of DFM had 20% thinner lamina propria than control steers. The authors suggested that the bacterial DFM decreases inflammation in the GIT, therefore spending less energy on cellular turnover and leaving more energy for animal growth (Elam et al., 2003). Because a DFM has the possibility to lessen the thickness of the lamina propria by decreasing inflammation, this allows for an increased ability for nutrients to be absorbed across the small intestinal wall.

Bacteriocins are produced by DFMs. They seem to limit the amount of bacterial growth and reproduction due to antimicrobial effects. Bacteriocins are a heterogenous group of ribosomally synthesized antibacterial peptides and proteins (McAllister et al., 2011) that are capable of inhibiting bacteria similar to harmful producing strains vying for the same ecological niche. Bacteriocins have the ability to target an array of organisms. Bacteriocins can be produced by either Gram-negative or Gram-positive bacteria which both contain two main classes: colicins and microcins for Gram-negative and lantibiotic and non-lantibiotic for Gram-positive (McAllister et al., 2011). Iverson and Millis (1976) were the first two researchers to report that bacteriocins could be produced by rumen microorganisms as they described antimicrobial activity by isolates of *Streptococcus bovis*. There is a chance for bacteriocin resistance within the rumen, which may influence the efficacy of the DFM (McAllister et al., 2011). There are a multitude of bacteriocins that have been extensively studied including CCM4231, HC5, subtilin and subtlosin A. CCM4231 is produced by *Enterococcus faecium*, and inhibits

the growth of *enterococci*, *staphylococci*, *listeria*, and *E. coli* in the rumen (Lauková and Czikková, 1998). The second was bovicin HC5, which is a lantibiotic produced by *S. bovis*. Bovacin HC5 was reported to limit methane production and amino acid degradation in the rumen (Lee et al., 2002; Lima et al., 2009). Subtilin and subtilosin A are the two primary bacteriocins studied from the *Bacillus* genus (Lee and Kim, 2011). These specific bacteriocins are recognized as lantibiotics and are composed of amino acids and are primarily utilized as an antibacterial against food spoilage and pathogenic microorganisms (Ahern et al., 2003; Stein, 2005). Subtilin is the most studied bacteriocin of the two and is produced by *Bacillus subtilis* ATCC 6633 and can inhibit a broad range of Gram-positive bacteria (Lee and Kim, 2011).

Signaling of the immune system response or immunomodulation is another important mechanism of action. The animal immune system is able to mount both innate and adaptive immune responses against a multitude of viruses and pathogens. Bacterial DFMs are able to have an effect on the innate, humoral, and cellular elements of the immune system (Krehbiel et al., 2003). The GIT contains the needed cells to fight off the prevalence of pathogens consumed. It provides a constant, protective defense against harmful bacteria and antigens from food by a number of mechanisms including up-regulation of cell-mediated immunity, increased antibody production, reduction of epithelial cell apoptosis, increased epithelial barrier integrity, and enhanced dendritic cell-T-cell interaction (Lee et al., 2010). These mechanisms can be supported by the reviews conducted by Erickson and Hubbard (2000) and Isolauri et al. (2001). They suggested that oral administration of lactobacilli typically resulted in innate immune responses, elevated production of immunoglobulin A (IgA) and decreased

immunoglobulin E production in both humans and animals. However, Elam et al. (2003) reported no effect on serum IgA concentrations when cattle were supplemented with a form of *L. acidophilus* or *P. freudenreichii*. Direct fed microbial influence on cytokine production along with T and B cell responses has been reported to be dependent upon the strain, dose, and duration of feeding the DFM, as well as the type of tissues and cells evaluated (Krehbiel et al., 2003).

In addition to the general modes of actions previously explained, different types or combinations of DFMs can have more targeted modes of action, which include feeding lactate-producing bacteria in conjunction with lactate-utilizing bacteria (Raeth-Knight et al., 2007). Seo et al. (2010) reported proposed mechanisms for both types of bacteria. The proposed mechanism for lactate-producing bacteria includes a constant lactic acid supply, adaptation of microflora to lactic acid accumulation, stimulation of lactate-utilizing bacteria and stabilization of rumen pH. The lactate-utilizing mechanisms include conversion of lactate to volatile fatty acids (VFA), increased production of propionate rather than lactic acid, increased feed efficiency, decreased methane production, and increased ruminal pH (Seo et al., 2010). Lactate-producing bacteria (*L. acidophilus*) help ruminal microorganisms adapt to the presence of lactic acid, whereas lactate-utilizing bacteria (*P. freudenreichii*) assist in reducing the buildup of lactic acid in the rumen (Kung and Hession, 1995; Ghorbani et al., 2002; Beauchemin et al., 2003). Owens et al. (1998) suggested that ingestion of excessive amounts of highly fermentable carbohydrates fed in high-concentrate diets led to increased cases of sub-acute and acute acidosis in cattle due to increased VFAs and accumulation of lactic acid within the rumen. Therefore, in most cases, lactate-producing and lactate-utilizing bacteria are fed in

combination to decrease the risk of acidosis and improve feed digestion in feedlot cattle fed high-concentrate diets (Beauchemin et al., 2003).

Huffman et al. (1992) fed ruminally fistulated steers a 50% concentrate diet supplemented with 5 x 10^8 cfu of *Lactobacillus acidophilus* for 12 days. On day 13, steers were fed a 100% concentrate diet to induce subacute acidosis. *L. acidophilus* reduced the amount of time ruminal pH was below 6.0 compared with control steers. In contrast, Ghorbani et al. (2002) fed 10/g/steer/d of a carrier that contained 1 x 10^9 cfu/g of *Propionibacterium* P15 or *Propionibacterium* P15 and *E. faecium* EF212 in a diet containing 87% steam-rolled barley to steers adapted to the high-concentrate diet. No effect was reported on ruminal pH, with the mean ruminal pH of the steers fed the steam-rolled barley being 5.71. Ruminal fluid concentrations of propionate, isobutyrate, and isovalerate, or the acetate:propionate ratio was not affected by *Propionibacterium* or combination of *Propionibacterium* and *E. faecium*. Ghorbani et al. (2002) also observed an increase in protozoa and decreased amylolytic bacteria within the rumen of the steers supplemented with *Propionibacterium*, indicating the decrease in amylolytic bacteria was due to the increase in protozoa as protozoa are predators of ruminal bacteria. Previous research indicates that a ruminal pH of 5.6 results in subacute acidosis and when the pH of the rumen is 5.2 or less, this results in a state of acute acidosis (Cooper and Klopfenstein, 1996; Owens et al., 1998). Acidosis is the result of cattle consuming excessive amounts of highly fermentable carbohydrates during both the adaptation phases of feeding and finishing periods, which leads to an abrupt increase in carbohydrate supply causing lactate and acid to accumulate within the rumen, causing a sharp decline in the ruminal pH (Owens et al., 1998). Huffman et al. (1992) and Ghorbani et al. (2002) both

observed pH readings above the subacute pH stated in previous research even though both sets of cattle were fed highly-fermentable diets. Direct fed microbial supplementation, when fed with high-concentrate diets, could aid in reducing the time ruminal pH spends under 5.6 or 5.2.

Probiotics in Ruminants

Probiotics can be classified as viable microbial cultures, enzyme preparations, culture extracts, or combinations of all three (Yoon and Stern, 1995). Probiotics can include both fungal and bacterial cultures (Krehbiel et al., 2003). Probiotics have been designed to promote maturation of the rumen microbiota, reduce the risk of pathogen colonization, improve feed efficiency, increase milk yield and quality in dairy cattle, promote weight gain and reduce acidosis (Chaucheyras-Durand and Durand, 2009).

Probiotics must be able to survive in extremely diverse and tough microbial ecosystems. The rumen environment can be harsh as it can have extreme fluctuations from a high to low pH and harbor harmful bacteria and pathogenic species. The probiotic must be able to withstand the constant up and downs and evade naturally occurring antimicrobial effects of the rumen. The GIT poses just as many threats as the rumen, therefore, probiotic strains metabolic activities and survivability throughout the rumen and GIT are highly important for optimal efficacy (Chaucheyras-Durand et al., 2008).

Yeast

Saccharomyces cerevisiae

AAFCO (1991) defines yeast culture as a dry product composed of yeast and the media on which it was grown, dried in such a manner as to preserve the fermenting capacity of the yeast. The media must also be stated on the label. The yeast biomass is dried in order to protect cell viability and metabolic activity, and sometimes mixed with a fermentation medium (Chaucheyras-Durand et al., 2008). *Saccharomyces cerevisiae* is the most common type of yeast fed in ruminant diets. Most yeast products contain extremely high concentrations of viable cells, up to or exceeding 10 billion cfu/g (Chaucheyras-Durand et al., 2008). There are a variety of *S. cerevisiae* strains utilized today, however, not all strains are capable of stimulating digestion within the rumen (Newbold and Wallace, 1992). The responses to yeast can vary due to the strain type, nature of the diet, and health of the animal. *S. cerevisiae* has been most commonly fed to dairy cattle and is reported to increase dry matter intake (DMI), rumen pH, VFA production, and organic matter digestibility while decreasing rumen lactate concentration (Phillips and VonTungeln, 1985; Cole et al., 1992; Keyser et al., 2007; Desnoyers et al., 2009; Fink et al., 2014).

Saccharomyces cerevisiae is also known as a fiber digester as there is evidence that it causes a shift in rumen bacterial populations, including increasing fiber-digesting bacteria and decreasing the amount of lactic acid within the rumen (McAllister et al., 2011; Swyers et al., 2014). The increase in fiber-digesting bacteria enables the animal to grow more efficiently with additional energy due to the increased fiber digestion (Wiedmeier et al., 1987). This specific type of yeast is aerobic (McAllister et al., 2011),

giving them the ability to utilize the small amounts of oxygen found within the rumen. However, yeast has been found to have a short life span within the rumen (Van Soest, 1994; Kung Jr. et al., 1997) therefore, it must be fed daily in order to make a long-term impact.

Mode of action: yeast

Over the years, researchers have worked to understand the mechanisms of action behind yeast supplementation. Many modes of action have been reported including increasing rumen microbial bacteria, increasing rumen pH, increasing fiber degradation and immunomodulation and gut motility to improve performance in the feedlot and decrease both morbidity and mortality rates (Newbold et al., 1995; Yoon and Stern, 1995; Callaway and Martin, 1997; Chaucheyras-Durand et al., 2008; McAllister et al., 2011; Broadway et al., 2015). In order for the rumen to develop and function correctly, establishing a complex microbial ecosystem is extremely critical. By developing a complex system, this allows the animal to correctly digest and absorb needed feed and nutrients, as well as develop a strong and healthy immune system (Hooper et al., 2001).

Several studies have demonstrated that yeast cultures consistently increase the number of total bacteria that can be recovered from the rumen (Yoon and Stern, 1995; Beauchemin et al., 2006; Chaucheyras-Durand et al., 2008). Researchers have agreed that increased numbers of cultural bacteria are the main action of yeast supplementation, which ultimately allows increased fiber-degradation in the rumen and an increased flow of microbial protein from the rumen (Offer, 1990; Marten and Nisbet, 1992; Wallace and Newbold, 1992; Dawson and Girard, 1997; Kung, 2001). Dawson and Hopkins (1991)

and Dawson (1993) both suggested that the individual yeast strains effect cellulolytic groups of ruminal bacteria differently due to the bacteria being selectively stimulated by certain individual strains. Most microorganisms found in the rumen are oxygen sensitive, thus, yeast must scavenge for oxygen which stimulates the growth of anaerobic bacteria (Rose, 1987; Newbold et al. 1996). Newbold et al. (1996) observed a correlation between the yeasts ability to stimulate oxygen uptake by ruminal fluid and the ability for yeast to stimulate the growth of rumen bacteria. However, Newbold et al. (1996) also reported that respiratory-deficient mutants of *S. cerevisiae* were unable to remove oxygen from rumen fluid, thus, failing to stimulate bacteria. However, the parent strains scavenged the oxygen allowing them to stimulate the rumen bacteria in rumen-simulating fermenters (Newbold et al., 1996). In order to determine these findings, most work with yeast strains has been completed *in vitro*.

Along with increasing microbial bacteria, yeast has been observed to provide the bacteria with different growth factors such as: organic acids, B vitamins, and amino acids, which aid in altering ruminal fermentation (Callaway and Martin, 1997). Nisbet and Martin (1991) and Callaway and Martin (1997) suggested that organic acids provided by the yeast may stimulate growth of lactic-acid utilizing bacteria, as well as the yeast providing a supply of B vitamins (niacin and thiamine) in order to alter ruminal fermentation (Brent and Bartley, 1984). These different growth factors have been reported to stimulate the growth and metabolism of lactate-utilizing bacteria (*Megasphaera elsdenii* or *Selenomonas ruminantium*) as the growth factors are essential components of lactate-fermenting bacteria (Nisbet and Martin, 1991; Rossi et al., 1995; Chaucheyras et al., 1996; Newbold et al., 1998; Rossi et al., 2004). These studies indicate

that live yeasts have the potential to increase rumen pH leading to a decrease in lactate accumulation within the rumen. Williams et al. (1991) reported that steers fed a hay plus barley diet supplemented with a yeast culture consistently lowered ruminal lactic acid concentrations. This led to, on average, a higher ruminal pH in the steers. Chaucheyras-Durand et al. (2008) hypothesized that active dry yeast products play a key role in lowering the rate of acid production in the rumen due to the ability to utilize starch and soluble sugars. Supplementing yeast in high concentrate diets has the possibility to decrease the number of cases of acidosis in feedlot cattle when supplemented on a regular basis. However, the effects of yeast supplementation on consistently stabilizing and increasing rumen pH may depend on the type of diet fed and strain of yeast (McAllister et al., 2011).

The stabilization of rumen pH is critical for the digestion of nutrients. If the rumen is in a state of sub-acute or even acute acidosis it can negatively affect fiber digestion (Russell and Wilson, 1996) as well as decreasing the total absorptive capacity of the ruminal epithelium (Krehbiel et al., 1995). Fiber-degrading bacteria is important for the stimulation of the microbes utilized in breaking down the insoluble structures of fiber such as cellulose and hemicellulose. Host enzymes in the rumen are unable to hydrolyze these molecules. Yeast has been observed to increase the rate of digestion (Fondevila et al., 1990) and decrease the time it takes to breakdown fiber within the rumen (Chademana and Offer, 1990; Girard and Dawson, 1995). Williams et al. (1991), Carro et al. (1992) and Dawson et al. (1990) reported similar results that an increase in fiber digestion was observed during the first 24 h after yeast was supplemented, however, after 48 h, digestion was not affected. These studies indicate that yeast culture may affect

time of fiber digestion within the rumen but can vary due to different strains of yeast. Callaway and Martin (1997) and Chaucheyras-Durand and Fonty (2001) reported accelerated rates of fiber digestion from *S. cerevisiae* and concluded that this acceleration was due to an increase in polysaccharidase and glycoside-hydrolase activities. Many of these beneficial effects could explain increased DMI when livestock are supplemented with a yeast culture.

As stated previously, yeast has many mechanisms of actions. Immunomodulation is a key reason why yeast-based supplements are fed to high-risk, newly received cattle in the feedlot. Calves are highly stressed at time of arrival due to a variety of factors. Chronic stress causes immunosuppression, making the calves more susceptible to infection with viruses or bacteria associated with bovine respiratory disease (BRD), the primary cause of mortality and morbidity among high-risk cattle in a feedlot. Direct fed microbials have been implemented into receiving diets to help mitigate the effects of stress on the immune system and protect against pathogen invasion and dysbiosis. Stressors can lead to altered microorganisms in the rumen (Williams and Mahoney, 1984) which can lead to decreased performance and increased morbidity and death loss. Yeast and yeast cell wall products derived from *S. cerevisiae* are suggested to be immunomodulating compounds that can act directly or indirectly with pathogens within the GIT (Kogan and Kocher, 2007). Not only do these products impact immune response, but the condition of the cattle prior to arrival and supplementation can determine whether the yeast or yeast cell wall product will have an impact on study outcomes. Cole et al. (1992) suggested cattle that are deemed high-risk or under greater stress may see a greater impact from the yeast supplement compared to low-risk cattle. Polysaccharides

such as α-D-glucan and β-D-glucan are able to indirectly interact with immune cells and bind to bacteria to prevent attachment and colonization of pathogens in the GIT (Ruiz-Herrera, 1992). In a recent review, Broadway et al. (2015) detailed how yeast and yeast derivatives are involved in the pro-inflammatory cytokine response, release of cytokines (IL-1, IL-2, and IL-6), as well as increase the functionality of macrophages and neutrophils. Broadway et al. (2015) suggested that yeast and yeast-based products may alter cytokine production and activation of the immune system due to the priming effects of β-glucans on immune cells, which can aid in mitigating subsequent infections.

Effects on health and performance

Direct fed microbials have many effects on livestock including immunomodulation and increased feed efficiency and performance. Many studies have reported probiotics to increase average daily gain (ADG) and improve feed efficiency in feedlot cattle; improve health and increase immunity among newly received calves; decrease potential of ruminal acidosis; alter rumen microflora populations and increase propionate concentrations within the rumen (Krehbiel et al. 2003; Guillen 2009). The ability for *S. cerevisiae* to produce consistent results in vivo has yet to be confirmed as experimental and environmental conditions differ among the experiments. A multitude of studies have evaluated *S. cerevisiae* supplementation to improve health, decrease morbidity and mortality, and improve feed efficiency and performance among newly received cattle; however, these studies have resulted in a variety of outcomes (Krehbiel et al., 2003).

Many of the studies observing the health impact of yeast-based DFMs utilized high-risk, newly received cattle in a feedlot. Fink et al. (2014) supplemented *S. cerevisiae* to steers upon arrival at the feedlot for the first 56 d on feed. Cattle either received the control (no yeast additive), live yeast at 10^{10} cfu/g and 5 g/d per animal, yeast cell wall at 5 g/d per animal and a combination of yeast and yeast cell wall at 5 g/d per animal live yeast and 5 g/d per animal yeast cell wall. No statistical differences were observed for morbidity or mortality rates among treatments, but yeast alone numerically decreased the mortality rates. The inclusion of yeast and yeast cell wall resulted in an increase in DMI during the 56-d feeding period when compared to control, but no difference was reported for BW, ADG, or feed efficiency (G:F) ratio. Keyser et al. (2007) conducted a three-part study observing the effects of *S. cerevisiae* supplementation with the administration of antibiotics upon arrival at the feedlot. They observed a decrease in the rate of cattle treated once or more for BRD and a decreased ratio for cattle likely to be treated again when compared to control heifers. Similar to Fink et al. (2014), they reported no treatment difference for ADG or G:F; however, they observed no difference in DMI when compared to control heifers. Cole et al. (1992) studied the impact of supplementing a S. cerevisiae culture to feeder calves and lambs. They reported that the yeast supplement did not significantly affect morbidity, mortality, or performance during the first two experiments. Calves supplemented with the yeast culture had a higher DMI than controls. Feeder lambs supplemented with yeast culture also had an increase in mineral absorption compared to control lambs.

Krehbiel et al. (2003) reviewed DFM supplementation in newly received cattle in the feedlot. His review reported no health benefits from DFM supplementation at

processing or when combined with feed for 50% of the publications included in the review. But, when studying the performance benefits of supplementing a bacterial DFM during the first 30 days after receiving, Krehbiel et al. (2003) reported that cattle fed the DFM had a 13% increase in ADG, 6.3% increase in feed efficiency, and consumed 2.5% more feed than their control cohorts. Smock et al. (2020) studied the effects of *Bacillus subtilis* PB6 and/or chromium propionate on the health, performance and carcass traits in high-risk cattle during the first 56 d after receiving. They conducted a 2 x 2 factorial using three hundred and eighty-four crossbred beef bulls and steers. Treatments consisted of control, 13 g/animal/d of *B. subtilis* PB6, 450 ppb DM chromium propionate, and 13 g/animal/d *B. subtilis* PB6 and 450 ppb DM chromium propionate. Smock et al. (2020) reported a treatment effect for cattle treated for BRD at least once, with a tendency for the same animals to be treated twice. Respiratory mortality did not differ among treatments; however, the control had numerically greater mortality (4.2%) than DFM supplemented groups. The *B. subtilis* PB6 treatment cattle had greater BW throughout the 56-d receiving period than CON treatment, had improved ADG from d 0 to 14, increased DMI each 14-d interim period, and tended to improve feed efficiency during the first 14 d on study (Smock et al., 2020). Deters et al. (2018) supplemented one hundred and eighty newly weaned Angus-crossbred steers with differing dosage levels of a *Saccharomyces cerevisiae* fermentation product (SCFP) during the first 56-d after feedlot arrival. Cattle received 1 of 3 dosage treatments: 0 g/steer, 14 g/steer or 28 g/steer. The SCFP supplementation resulted in no treatment effect on final BW, DMI, ADG, or feed efficiency from d 0 to d 56. However, they did observe a quadratic effect of SCFP on percentage of BRD treatments prior to d 14 of the study with the 14 g/steer dose requiring

the greatest number of treatments. Similar to the results reported by Deters et al. (2018) and Mir and Mir (1994), Lockard et al. (2020) observed no difference in DMI, ADG, or feed efficiency in beef steers supplemented with a yeast-based additive.

Phillips and VonTungein (1985) conducted a four-part study and reported an increase in DMI and ADG in newly received feeder calves from the addition of a yeast culture in the receiving diet in two of the trials, but no effect on performance in the other two trials. In a review conducted by Duff and Galyean (2007), cattle supplemented with a yeast product had improved performance even when exposed to BRD. McDonald et al. (2005) evaluated records on 73,870 feedlots containing 10,900,504 cattle. Feedlots that utilized DFMs reported increased ADG of 1.9 and 1.4% for steers and heifers, respectively. Feed efficiency also had reported improvements of 1.9 and 3.9% for steers and heifers, respectively. Wagner et al. (2016) conducted a meta-analysis reporting the effects of supplemented SCFP on feedlot performance and carcass traits for eighteen different experiments. Of the eighteen experiments, nine were receiving studies. Initial BW and DMI was similar among control and SCFP cattle; however, at the end of the receiving period, SCFP fed cattle were 2.3 ± 0.79 kg heavier than control cattle. Average daily gain and feed efficiency were improved by 5.8 and 2.0%, respectively, for SCFP cattle compared to controls. Wagner et al. (2016) also included the interaction of SCFP on days on feed (DOF) by DMI during the finishing period. They observed a DMI increase of 5.7% compared to control cattle when fed for 100 days, and an 8.8% increase in DMI compared to control cattle when fed for 200 days. Overall, the meta-analysis concluded that cattle fed SCFP showed significant increases in final BW (2.9 kg), ADG (6.5%), DMI (1%), and feed efficiency (2.6%) versus the control cohorts.

Bacteria and yeast-based strains are often combined to study the effects that a multi-strain DFM might have on health and performance. Multi-strain bacterial and yeast DFMs intend to combine the "best of both worlds" to have the most successful combination in order to meet the needs of the livestock being fed. Adeyemi et al. (2019) examined the effects of a blend of *S. cerevisiae-based* DFM and fermentation product on newly weaned beef steers for the first 42 d after feedlot arrival. The DFM treatment was an optimized blend of 6.2 x 10^{11} cfu/g of *S. cerevisiae*, 3.5 x 10^{10} cfu/g of a mixture of *Enterococcus lactis*, *Bacillus subtilis*, *Enterococcus faecium*, and *L. casei*, *Aspergillus oryzae*, and *A. niger*. The DFM mixture significantly increased final BW and ADG over the 42-d feeding period, but had no effect on DMI. Adeyemi et al. (2019) reported a tendency for improved feed efficiency in steers supplemented with the DFM mixture compared to control steers. In contrast, Stephens et al. (2010) observed no treatment differences in ADG or feed efficiency between cattle fed a mixed DFM (*S. cerevisiae* strain and *Lactobacillus acidophilus* strain) compared to the control treatment. The control treatment received the standard feedlot diet while the group fed the DFM received the basal diet plus 400 mg/animal/d of a mixed DFM containing 8 x10^{9} cfu *S. cerevisiae* strain BP-31702 and 5 x 10^{8} cfu *L. acidophilus* strain BT-1386. Although the cattle supplemented with the DFM were 3.2 kg heavier on average at slaughter, no treatment effects on growth performance were reported (Stephens et al., 2010).

There are a multitude of variables that impact the health and performance of cattle in a feedlot. Health risk of calves on arrival, product delivery, DFM types and strains being tested, and nature of the diet can all impact the health and performance of livestock, which could explain the variable results observed in DFM research thus far.

Variability in today's research and the future of DFMs in commercial feedlots

Throughout this review, many reasons on why DFMs impacts are highly variable in research were addressed. Whether the DFM being supplemented was strictly bacterial, a single strain, a yeast, or a combination of both, are reasons why results often contradict and results are further confounded by the diets being fed at the time of the study, the dosage level of the DFM and the duration the DFM was being supplemented. The continual inconsistency of data from DFM studies make us question the efficacy of DFM being fed in today's commercial feeding sector. Often times, performance, feed efficiency and health data show either positive or no results at all in DFM studies. Ponce et al. (2011) supplemented ninety-six steers with either a control or a 200 mg microencapsulated DFM containing a mixture of lactate-producing bacteria and digestive enzymes. They reported no effect on final BW or feed efficiency but observed DFM treated cattle had a greater DMI and ADG than controls. Conversely, Encinas et al. (2018) reported no treatment effect for average DMI or feed efficiency but observed that control cattle had increased ADG versus cattle fed the DFM (1.76 kg versus 1.56 kg). Compared to Ponce et al. (2011), only 30 crossbred steers were fed and the DFM supplement contained a yeast plus DFM and digestive enzymes at 30 g/animal/d. The number of cattle used in experimental research specific to feedlots is limited and is another contributor to variability in available DFM testing results.

The type of DFM play a major role in how the DFM is going to interact with the livestock; however, the complex microbial ecosystem found within the GIT of livestock presents its own troubles. The microbiome of the animal is constantly changing with age, exposure to different microbes and components of the diets (Buntyn et al., 2016). Not

only does the microbiome of the GIT play a vital role in nutrient digestion and absorption, but as stated earlier is key in the immune systems' development. Researchers must first gain a better insight into the relationship between the host and microbiome in order to better correlate the correct DFM genus type and dosage needed to best suit a specific type of livestock (Buntyn et al., 2016). Newbold (1995) demonstrated that production response and ruminal characteristics can be highly variable to yeast supplementation. Girard and Dawson (1995) reported that not all strains of *S. cerevisiae* are capable of stimulating ruminal fermentation.

Methods of delivery is another variable among research. Methods have ranged from supplementation of the dam with a DFM, to single-dose, oral administration, direct supplementation through the diet, and other complex combinations. These methods were fed for varying average lengths of time, anywhere from 28 to 56 days during the receiving period, or throughout the feeding period until slaughter.

Direct fed microbials have the potential to play an important role in the cattle feeding sector, and although recent research in bacterial and yeast-based DFM has made improvement in better understanding the modes of action behind these supplements, further research is needed to ensure that all DFM products on the market return consistent and efficacious results. As stated previously, there are 42 individual species of microorganisms approved for use as DFM's by the FDA. These microorganisms fall under GRAS standards, however, there is nothing that states that these microorganisms, specifically when combined, must be efficacious. Thus, product companies can use any combination of the 42 species to make a DFM, market and sell without knowing the efficacy of the actual product. This is a major variable in whether a DFM is going to be

successful as a feed additive or not. Antibiotic resistance and continuous use of ionophores and other feed-grade antibiotics in ruminant diets pose a challenge to beef production in the future. This challenge provides impetus for DFM supplements to be researched and utilized if efficacious. However, we must have a full understanding of how bacterial strains or yeast, or combination of both, affect livestock on feed if they are to become a viable alternative to antibiotics.

Conclusions from the Literature

Results of bacterial and yeast-based DFM supplementation in commercial beef feeding systems is highly variable due to differences in environment, bacterial strains, type of cattle being fed, DFM dosage, source, duration, and nature of the diets. Improvements from DFM reported on health or performance are variable, and more research is needed in order to fully understand the mode of action behind these DFM to effectively utilize them in a feedlot setting. Thus, the objective of this thesis research is to evaluate the effects of feeding a yeast-based probiotic-prebiotic during the first 21 or 42 days of the receiving period on performance, health, and carcass characteristics of beef cattle.

MATERIALS AND METHODS

All methods and procedures involving live animals were approved by the West Texas A&M University Animal Care and Use Committee (#2019.08.003).

Cattle Management

Two hundred and fifty-eight (BW = 250 ± 11.4 kg) crossbred steers of southern Texas origin arrived at the Texas A&M AgriLife Research feedlot in Bushland, TX. Two hundred and forty steers were used in a randomized complete block design experiment to evaluate the effects of a probiotic-prebiotic blend (P-PB) on feedlot performance during the receiving and finishing period. Steers arrived in three separate loads (d -9, d -7, and d -2) with 86 steers per truck load. Upon arrival, steers were placed into receiving pens with fresh water, and gate sorted by 10 steers per sort to 30 open-aired feedlot pens where they had ad libitum access to long-stem hay and water. After the final load arrived, steers were allowed 24 hours of rest before they were weighed individually (d -1; Lonestar Livestock Equipment, Houston, TX; Tru-Test Inc., Mineral Wells, TX; readability ± 0.45 kg; validated with certified weights before each use) and given an individual visual ear tag and electronic identification (EID) tag and returned to their original holding pens.

Treatment and Experimental Design

From the d -1 BW, steers were allocated to 1 of 2 weight blocks. Within each weight block, steers were allocated to 1 of 30 experimental pens. Experimental pens were randomly assigned 1 of 3 receiving treatment diets (Table 1); 1) steam-flaked corn-based step-up and finishing diets without P-PB (CON); 2) steam-flaked corn-based step-up diets with P-PB for 21 days after arrival (P-PB21); and 3) steam-flaked corn-based step-up and finishing diets with P-PB for 42 days after arrival (P-PB42). The probiotic-prebiotic supplement includes: grain products, vegetable oil, silicon dioxide, artificial flavors, processed grain by-products, yeast extract (Saccharomyces cerevisiae), active dry yeast (Saccharomyces cerevisiae), saccharin sodium, glycyrrhizin ammoniated, sodium silico aluminate, calcium carbonate, chromium propionate, mineral oil, dried Enterococcus lactis fermentation product, dried Bacillus licheniformis fermentation product, and dried Bacillus subtilis fermentation product (RX3; Land O'Lakes Inc.; Arden Hills, MN). On d 0, steers were weighed individually and placed in their respective experimental pens. Body weights recorded on d -1 and d 0 were averaged to calculate initial BW. Individual BW were recorded on d -1, 0, 21, 42, and trial termination, with average pen weights recorded every 21 d after the end of supplementation until trial termination. Steers within the heavy weight block were fed out for 254 d, whereas steers within the light block were fed out for 268 d. Weight blocks were harvest on two separate dates, two weeks apart with the heavy block harvest first.

Health Management

On d -1 steers were administered a vaccine for clostridial disease (UltraChoice 8; Zoetis; Kalamazoo, MI), *Mannheimia haemolytica* (Presponse SQ; Boehringer Ingelheim; Duluth, GA), an injectable anthelmintic (Dectomax Injectable; Zoetis; Kalamazoo, MI), and an oral anthelmintic (Valbazen Suspension; Zoetis; Kalamazoo, MI). Steers were evaluated for health, lameness, and injuries daily by trained feedlot staff. On d 21, steers received a vaccination with modified live virus strains of infectious bovine rhinotracheitis (IBR), bovine viral diarrhea virus (BVDV) (Types 1 and 2), parainfluenza 3 (PI3), and bovine respiratory syncytial virus (BRSV) viruses (Bovi-Shield Gold 5; Zoetis; Kalamazoo, MI) and an implant with 80 mg of trenbolone acetate (TBA) and 16 mg estradiol (Revalor-IS; Merck Animal Health; DeSoto, KS). Steers were re-implanted on d 105 with 200 mg TBA and 40 mg estradiol (Revalor-XS; Merck Animal Health; DeSoto, KS). During the time in which loads were received and before the start of the P-PB treatment, steers suspected of BRD were given a clinical score, 1 to 4, based off severity of symptoms. Steers with a BRD score of 2 must have had a rectal temperature ≥ 40° C to be treated while steers with a BRD score of ≥ 3 were treated immediately. Steers were administered tulathromycin (Draxxin; Zoetis; Kalamazoo, MI) for the first treatment. Steers treated a second time received florfenicol with flunixin meglumine (Resflor Gold; Merck Animal Health; DeSoto, KS); if treated a third time, steers received ceftiofur (Excede; Zoetis; Kalamazoo, MI) and if a fourth treatment was needed, steers received tildipirosin (Zuprevo; Merck Animal Health; DeSoto, KS). A total of thirty-six steers were treated before start of the 42-day trial for BRD symptoms, and five died from respiratory illness. Steers treated once before trial initiation were

either removed from the study or divided evenly across treatments during allocation. Due to factors unrelated to treatment, such as BW or truckload arrival date, one steer receiving the P-PB21 treatment and one steer receiving the P-PB42 treatment were removed from the study.

Feed Management

The P-PB treatment was delivered via a pellet based on the average pen DMI. When DMI was < 6.35 kg, P-PB inclusion was 8.75 % DM of the diet. When DMI was ≥ 6.35 kg, P-PB inclusion was 6.25 % DM of the diet. In order to determine the rate of inclusion within the diet, DMI and feed refusals were recorded daily in order to calculate for corrected DMI. Every 7 d, average pen DMI was used to determine the inclusion rate of the P-PB pellet for the next step-up ration. Once pens were consuming ≥ 6.35 kg DMI, pellet inclusion was decreased and SFC increased in place of the percentage difference of P-PB pellet. The CON experimental treatment received the same pellet without P-PB at a similar inclusion rate. When P-PB was removed from the P-PB21 treatment diet, the CON pellet was fed for the remaining 21 days of the receiving period. All steers received a similar receiving diet which consisted of 66 % concentrate and 34 % roughage on a dry matter basis. Steers were transitioned to a steam-flaked corn-based finishing diet consisting of 92 % concentrate and 8 % roughage on a dry matter basis over the first 21 d of the study. Each diet, the starter, step-up ration 1 and step-up ration 2 were all fed for 7 day until moving on to the next step-up ration until reaching the finishing diet on d 21. Diets contained monensin sodium (38 g/T; Rumensin, Elanco Animal Health; Indianapolis, IN), and tylosin (8 g/T; Tylan, Elanco Animal Health; Indianapolis, IN),

and vitamins and minerals were formulated to meet or exceed NASEM (2016) requirements (Table 1). Steers were fed once daily at approximately 0700 h. Diets were mixed in a stationary mixer mounted on load cells (Roto-Mix 274-12B, Roto-Mix Dodge City, KS; Digi-Star, Fort Atkinson, WI, readability ± 0.45 kg) and timed to allow 5 min of closed-door mixing. Feed was negatively weighed from the stationary mixer and delivered using an individual feed hopper that distributed the amount of feed for a single pen. Bunks were managed such that ≤ 0.45 kg of dry orts remained in the bunk prior to that day's feeding. Any feed remaining in the bunk before steers were weighed was removed from the bunk, weighed, and dried at 60° C for 48 h. Diet and ingredient samples were collected weekly for DM, weighed and dried at 60° C for 48 h, and composited by mo. Proximate analysis of individual ingredient samples was completed by a commercial laboratory (Servi-Tech; Amarillo, TX).

Statistical Analysis

Feedlot performance data were analyzed using the MIXED procedure of SAS 9.4 with pen as the experimental unit, weight block as a random effect, and treatment as a fixed effect. For mean separation, the LSMEANS statement with the PDIFF option was performed and performance LSMEANS was adjusted using Tukey's, while model was ran with the Kenward Roger adjustment for degrees of freedom. Categorical data were analyzed using the GLIMMIX procedure. For all analyses, effects were considered significant at a $P \leq 0.05$, and a tendency when $P \leq 0.10$ and > 0.05.

RESULTS AND DISCUSSION

Performance Characteristics

No dietary treatment effects were observed during the first 42 d (days 0 to 42) for BW ($P \geq 0.91$), ADG ($P = 0.97$), DMI ($P = 0.95$), or G:F ($P = 0.99$). Average daily gain from d 0 to d 21 was lower for the CON compared to P-PB42 (1.42 kg/d vs. 1.54 kg/d), respectively. No treatment effects were observed for growth measures during the finishing period as all treatments had similar BW, ADG, DMI, and feed efficiency ($P \geq 0.30$).

Adeyemi et al. (2019) studied the effects of a blend of Saccharomyces cerevisiae – based DFM and fermentation products on newly received beef steers during a 42-d receiving period. Comparatively, they observed an increase in d 42 BW and ADG but no effect on DMI. Similar to our results, no treatment effects were observed during the first 21 d; however, Adeyemi et al. (2019) observed a positive treatment effect during the final 21-d on treatment for ADG and feed efficiency for steers fed the supplemented DFM. The multistrain *Saccharomyces cerevisiae* – based DFM fed in the study favored lactic-acid utilizing bacteria that metabolize lactate to propionate, which is a major precursor to glucose synthesis and fiber-digesting bacteria (Martin and Nisbet, 1992; Newbold et al., 1996; Callaway and Martin, 1997; Nagaraja and Titgemeyer, 2007; McAllister et al., 2011). Glucose synthesis is important to a ruminant because glucose is continually

broken down by glycolysis to create adenosine triphosphate (ATP), which is a form of energy utilized by the animal. *Saccharomyces cerevisiae* has been found to increase cellulolytic bacteria within the rumen (Chaucheyras et al., 1995; Ogunade et al., 2019) which can alter the rumen fermentation pattern and increase fiber digestibility by causing an increase in rumen pH which allows for increased growth and activities of fiber-degrading bacteria. This mechanism may explain the increase in feed efficiency during the last 21 d of the study (Adeyemi et al., 2019).

Other studies feeding multistrain DFM have reported no effects on growth or feed efficiency (Kenney et al., 2005; Fink et al., 2014; Cole et al., 1992). Mir and Mir (1994) also reported no difference in DMI, ADG, or feed efficiency when supplementing *Saccharomyces cerevisiae* to growing beef cattle. Additionally, Lockard et al. (2020) reported no effect on initial, d 76 or final BW on beef steers supplemented with a yeast-based additive complex, as well as no treatment effect for ADG, DMI or feed efficiency during the time of treatment supplementation. Stephens et al. (2010) studied the effect of a DFM (*Saccharomyces cerevisiae* strain and *Lactobacillus acidophilus* strain) on performance and observed no treatment differences in ADG or feed efficiency between DFM and the control treatment.

Health

No treatment effects were observed for the percent of cattle treated for BRD once ($P = 0.65$) or twice ($P = 0.63$), or incidence of respiratory mortality ($P = 0.38$) during the first 42 d. There were no differences in days to first or second treatment ($P \geq 0.65$), average rectal temperature per treatment ($P \geq 0.64$), or average BRD score per treatment

(P = 0.40) throughout the 42-d receiving period. There was a two-fold increase in the percentage of CON supplemented steers treated for BRD a second time compared to their P-PB supplemented cohorts (5.0 % vs. 2.51 % for P-PB21 and 2.50 % for P-PB42, respectively); but no statistical difference was observed (P = 0.63). Two steers from the CON group were treated three times for BRD, while one steer on P-PB21 treatment and one from the P-PB42 treatment were treated for BRD four times during the receiving period.

Smock et al. (2020) observed the effect of *Bacillus subtilis* PB6 and chromium propionate supplementation on clinical health of newly received beef cattle. A treatment effect was reported for cattle treated for BRD at least once with a tendency for the same animals to be treated twice. Similar to our results, no treatment effect was observed for days to first or second treatment or rectal temperature at first or second treatment. In addition, Deters et al. (2018) reported no effect of a *Saccharomyces cerevisiae* fermentation product (SCFP) on respiratory treatments after d 14 but noted a quadratic effect on percent BRD treatments prior to d 14.

Krehbiel et al. (2003) reviewed studies with DFM supplementation in newly received feedlot cattle and observed variable health results, with half of the publications reporting no benefits, from supplementing DFM on health at processing or in the feed. McDonald et al. (2005) studied the effect of DFM on mortality of cattle weighing less than 320 kg and cattle weighing 320 to 365 kg. Although they reported death loss was lower for cattle fed DFM weighing between 320 to 365 kg, no differences were observed for death loss in cattle weighing less than 320 kg when fed DFM compared to control. Fink et al. (2014) reported positive physiological effects on health in newly received

cattle supplemented with a yeast-based product. The positive effects included increased feed intake that led to increased growth rate, decreased total mortality and number of cattle receiving multiple antibiotic treatments, lesser stress hormone levels and lesser overall body temperature. A variety of variables such as, health risk of cattle arriving at the feed yard, product delivery, DFM types tested, and diet, can affect cattle health, which may explain why health results from studies supplementing a DFM are variable.

Carcass Characteristics

Hot carcass weight (HCW) tended ($P = 0.09$) to be greatest for CON treatment with P-PB42 supplemented steers having the least amount of carcass weight. Steers fed the CON supplement had a greater dressing percent when compared to P-PB42 steers, ($P < 0.05$; 62.5 vs. 61.8%, respectively). No treatment effects were observed for longissimus area (LM; $P = 0.21$), back-fat thickness ($P = 0.62$), or marbling score ($P = 0.21$). Additionally, liver score ($P \geq 0.16$), yield grade ($P = 0.85$), and quality grade ($P \geq 0.24$) were also observed to have no differences for steers supplemented the probiotic-prebiotic compared to CON steers. No differences were observed across treatments for liver score ($P \geq 0.23$).

In a study done by Geng et al. (2015), forty-five finishing bulls were either fed no supplement, an active dry yeast supplement, or a yeast cultures supplement and the impact of supplementation on growth performance, carcass characteristics, meat quality, and blood indexes were observed. After 98 d, the bulls were slaughtered and no treatment differences were observed for DP, LM area, back-fat thickness, or weight of high-grade cuts such as the ribeye or sirloin. Paulus et al. (2012) reported no differences in HCW,

DP, LM area, and back-fat thickness in cattle fed *Saccharomyces cerevisiae* fermentation products. Titi et al. (2008) observed the effect of a supplemental yeast culture on thirty Friesian male calves for 294 d. No treatment effect was observed for fat thickness, DP, LM area or carcass merit. Krehbiel et al. (2003) reported that steers fed a DFM had greater final BW and HCW than control steers, but no statistical difference for DP, quality grade (QG) or percent choice was reported. Lockard et al. (2020) observed no DFM effect on HCW, fat thickness, LM area, marbling score, or QG, but there was a tendency for DP to be greater for control steers compared to DFM fed steers. Crossland et al. (2019) reported the effects of yeast on steers' ruminal pH and liver health and observed no differences in liver abscess prevalence across treatments, which is similar to our liver results.

IMPLICATIONS

Breed, prior management, diet, health risk, environment, and type and duration of DFM supplementation are all factors that affect cattle health and performance in the feedlot. No differences in cattle health or growth performance occurred due to supplementation of the yeast-based DFM during the receiving period. Further research is needed to better assess the effects of P-PB on receiving cattle performance. Due to the high variability in DFM products in the market, further understanding of the relationship between environmental factors, animal factors, and DFM dose, source, and strain will be critical in effectively using DFM in a feedlot setting.

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Table 1: Calculated nutrient composition

	Starter Diet	Step 1 Diet	Step 2 Diet	Finisher Diet
Ingredient, % DM				
Steam flaked corn	29.4	42.9	52.3	59.8
Cottonseed meal	18.1	17.6	17.7	15.8
Corn stalks	10.7	10.3	10.3	8.2
Haygrazer	25.0	13.6	3.7	0.0
Corn oil	1.4	1.6	1.6	1.8
Urea	0.3	0.3	0.3	0.3
Limestone	0.0	0.0	0.5	0.0
Supplement[1]	3.0	3.6	3.6	3.8
Molasses	3.3	3.6	3.6	3.6
P-PB Pellet[2]	8.3	6.4	6.1	6.5
Calculated nutrient composition				
CP, %	13.97	13.79	13.85	13.63
NDF, %	31.29	23.94	18.96	15.34
Fat, %	2.94	3.33	3.53	3.89
Calcium, %	0.56	0.54	0.49	0.58
Phosphorus, %	0.32	0.32	0.32	0.32
Sulfur, %	0.16	0.14	0.14	0.15
Sodium, %	0.12	0.12	0.12	0.13
NE_m, Mcal/kg	1.58	1.75	1.85	2.08
NE_g, Mcal/kg	0.94	1.09	1.20	1.37

[1] Formulated to provide 38 g/T monensin, 8 g/T tylosin and vitamins and minerals to meet or exceed NASEM (2016) requirements.

[2] Steers received the probiotic-prebiotic pellet at a rate of 8.75% DM inclusion when DM intake was < 6.35 kg/d and 6.25% DM inclusion when DM intake was ≥ 6.35 kg/d. Control steers received a placebo pellet without the probiotic-prebiotic supplement at the respective inclusions. Pellet included: Yeast extract (*S. cerevisiae*), active dry yeast (*S. cerevisiae*), chromium propionate, dried *Enterococcus lactis* fermentation product, dried *Bacillus licheniformis* fermentation product, and dried *Bacillus subtilis* fermentation product.

Table 2. Effect of a supplemental probiotic-prebiotic on growth performance, dry matter intake and feed efficiency on beef cattle during the feedlot receiving and finishing period

	Treatment[1]				
Item	CON	P-PB21	P-PB42	SEM[2]	*P*-value
Pens, *n*	10	10	10		
Steers, *n*	79	79	77		
Initial SBW[3], kg	249	251	251	4.47	0.97
d 0 to 21					
BW, kg	298	301	303	6.50	0.91
ADG, kg/d	1.42	1.46	1.54	0.11	0.73
DMI, kg/d	6.4	6.2	6.4	0.28	0.89
G:F	0.20	0.22	0.22	0.01	0.51
d 22 to 42					
BW, kg	317	318	319	6.01	0.98
ADG, kg/d	2.08	2.00	1.96	0.07	0.46
DMI, kg/d	9.1	9.1	9.1	0.22	1.00
G:F	0.21	0.20	0.20	0.01	0.56
d 0 to 42					
ADG, kg/d	1.75	1.73	1.75	0.06	0.97
DMI, kg/d	7.70	7.63	7.73	0.24	0.95
G:F	0.21	0.21	0.21	0.01	0.99
Cumulative d 0 to harvest					
Final SBW[4], kg	671	664	662	5.29	0.47
ADG, kg/d	1.62	1.59	1.58	0.02	0.39
DMI, kg/d	9.04	9.04	8.79	0.13	0.30
G:F	0.179	0.176	0.18	0.003	0.50

[1] Steers received the probiotic-prebiotic pellet at a rate of 8.75% DM inclusion when DM intake was < 6.35 kg/d and 6.25% DM inclusion when DM intake was ≥ 6.35 kg/d. Control steers received a placebo pellet without the probiotic-prebiotic supplement at the respective inclusions. Pellet included: Yeast extract (*S. cerevisiae*), active dry yeast (*S. cerevisiae*), chromium propionate, dried *Enterococcus lactis* fermentation product, dried *Bacillus licheniformis* fermentation product, and dried *Bacillus subtilis* fermentation product.
[2]Standard error of the mean.
[3]Initial Shrunk BW = average BW of day -1 and day 0 with a 4% shrink.
[4]Final Shrunk BW= BW taken on day of harvest with a 4% shrink.

Table 3. Effect of a supplemental probiotic-prebiotic on health outcomes on beef cattle during the receiving period

	Treatment[1]				
Item	CON	P-PB21	P-PB42	SEM[4]	*P*-value
Pens, *n*	10	10	10		
Steers, *n*	79	79	77		
BRD1[2], %	13.75	19.94	13.75	-	0.65
BRD2[3], %	5.00	2.51	2.50	-	0.63
Respiratory Mortality, %	2.50	0.00	2.50	-	0.38
Days to					
1st treatment	3.4	4.5	2.4	1.84	0.65
2nd treatment	9.0	5.0	8.0	6.32	0.89
Rectal Temperature, °C					
1st treatment	40.8	40.8	40.6	0.18	0.70
2nd treatment	38.9	40.6	39.1	1.23	0.64
Average BRD score					
1st treatment	2.6	2.3	2.6	0.19	0.40

[1] Steers received the probiotic-prebiotic pellet at a rate of 8.75% DM inclusion when DM intake was < 6.35 kg/d and 6.25% DM inclusion when DM intake was ≥ 6.35 kg/d. Control steers received a placebo pellet without the probiotic-prebiotic supplement at the respective inclusions. Pellet included: Yeast extract (*S. cerevisiae*), active dry yeast (*S. cerevisiae*), chromium propionate, dried *Enterococcus lactis* fermentation product, dried *Bacillus licheniformis* fermentation product, and dried *Bacillus subtilis* fermentation product.
[2]Percentage of cattle treated for BRD at least once.
[3]Percentage of cattle treated for BRD at least twice.
[4]Standard error of the mean

Table 4. Effect of a supplemental probiotic-prebiotic on carcass traits

	Treatment[1]				
Item	CON	P-PB21	P-PB42	SEM[2]	*P*-value
Pens, *n*	10	10	10		
Steers, *n*	76	76	75		
Dressing Percent, %[3]	62.5[a]	62.2[ab]	61.9[b]	0.18	0.05
Hot Carcass Weight, kg	419	413	410	3.06	0.09
Ribeye Area, cm^2	94.8	94.1	92.1	1.22	0.28
Marbling score[4]	570	596	587	14.29	0.44
Fat Thickness, cm	1.38	1.47	1.40	0.07	0.60
Calculated Yield Grade	3.0	3.1	3.1	0.10	0.85
USDA Quality Grade, %					
Standard	1.3	0.0	0.0	-	0.39
Select	43.4	32.0	35.5	-	0.35
Choice	38.2	52.0	47.4	-	0.24
Premium Choice	15.8	16.0	15.8	-	0.99
Prime	1.3	0.0	0.0	-	0.38
Liver Score, %					
Edible	72.4	82.7	76.4	-	0.33
Abscess	6.7	3.9	11.9	-	0.23
Flukes	10.5	5.4	4.0	-	0.25

[1] Steers received the probiotic-prebiotic pellet at a rate of 8.75% DM inclusion when DM intake was < 6.35 kg/d and 6.25% DM inclusion when DM intake was ≥ 6.35 kg/d. Control steers received a placebo pellet without the probiotic-prebiotic supplement at the respective inclusions. Pellet included: Yeast extract (*S. cerevisiae*), active dry yeast (*S. cerevisiae*), chromium propionate, dried *Enterococcus lactis* fermentation product, dried *Bacillus licheniformis* fermentation product, and dried *Bacillus subtilis* fermentation product.

[2] Standard error of the mean.

[3] Dressing percent calculated as (HCW / Final Shrunk BW)*100

[4] Marbling score 500 = modest[00] and 600 = moderate[00].

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