MANAGING FEED DELIVERIES AND OPTIMIZING INCLUSION OF NON-ANTIBIOTIC FEED ADDITIVES AND SUPPLEMENTAL SUGAR IN A CATTLE FEEDING PROGRAM

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ABSTRACT

Feedlot management strategies are ever changing. Consumer perspectives, commodity market fluctuations, location, weather and demand of beef are only a few aspects that drive feedlot manager's management decisions. Recent consumer push back towards the use of antibiotics in the cattle sold for beef has resulted in industry and academia to develop non-antibiotic alternatives to supplement calves during the receiving period. Therefore, a 49 d study was conducted to understand the effect of blended DFM, prebiotics and probiotics on receiving cattle. By day 7, cattle fed either additive had greater ADG, improved feed efficiency which continued throughout the 49 d study ultimately resulting in greater final BW compared to cattle not supplemented a nonantibiotic feed additive. In addition to improved performance parameters, health of supplemented cattle was also improved over the 49 d study in terms of decreased morbidity.

Market fluctuations and increase in HCW has also directed cow/calf and feedlot producers to grow cattle prior to feeding a high concentrate diet. However, due to the location of some of these producers being primarily in areas of high forage production and pasture land, at times corn availability can be scarce and expensive requiring the need for an alternative energy source. A 70 d study was conducted in an effort to determine the optimum sugar inclusion, in the form of cane molasses, in a high forage backgrounding diet. Results from this study revealed replacing up to 10.5% of starch with sugar led to no adverse effects on intake or growth performance and energy content, and this inclusion was comparative to that of corn grain.

A management strategy that continues to challenge feeders across the country is controlling variation in DMI. However, challenges in measuring variation in intake are often due to the fact that intake is determined as feed delivered on a pen basis. A considerable amount of research has been completed to understand performance responses to fluctuations feed delivered and frequency of delivery. Due to quantity of precipitation in a year in the Midwest, changes in DM of ingredients may also fluctuate DMI of cattle fed high concentrate diets. For that reason, an 84 day study was completed to understand whether as-fed dietary composition adjustments are necessary as feed ingredient DM content changes and to validate on-farm feed ingredient dry matter determination methods. Results of this study revealed adjusting as-fed dietary composition due to changes in DM content of feed ingredients daily resulted in no benefit over adjusting as-fed dietary composition every 28 d. Using a microwave and Koster tester to determine hay and corn silage DM, respectively, resulted in DM that were similar to those using laboratory procedures. However, DM estimated of high moisture corn using a Koster tester were different than DM determined using laboratory procedures.

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CHAPTER I

REVIEW OF LITERATURE

Introduction

Modern cattle feeding began after World War II (Dethloff and Nall, 2010). Small, simple farms, in which families operated with only enough livestock to meet their needs, began to expand into operations to finish cattle using greater dietary concentrations of grain. In the early 1950's, the industry began to understand how grain feeding led to more cost-effective cattle feeding. Cattle in confinement rather began, while concurrently, producers began buying cattle to feed instead of only feeding those they raised. Although transportation of livestock maximized resources allowing cattle to be calved in the spacious, dry South and finished in the fertile Midwest (Love, 1916), transportation of cattle also facilitated disease transmission. Producers began to vaccinate cattle to improve the longevity and health of their herds. Antibiotics became increasingly popular to not only treat humans, but livestock as well. However, as of recently due to consumer pushback, the use of feed grade antibiotics in animal production is feared to be soon a technology of the past. This is driving increasing interest to find alternative solutions to prevent and/or treat BRD in the feedlot, particularly during the receiving phase.

In addition to alternatives to antibiotics, alternative feedstuffs, otherwise called by-products, serve producers as sources of more affordable protein or energy. Particularly, producers in regions where corn, wheat or barley are more expensive and less available, are in search of an alternative high energy feedstuff to replace traditional energy feeds. Supplementing molasses in the feedlot has been utilized traditionally to serve as a carrier for NPN, ionophores, and vitamin and minerals (Broderick et al., 2008;

Felix et al., 2018). Molasses in cow-calf and dairy operations is primarily used as an energy and urea carrier when feeding low-quality forages (Heldt et al., 1999); Thus, intriguing researchers to examine the potential to substitute molasses for corn in backgrounding diets.

However, as technologies and tools to improve cattle production become more available, it remains important to understand basic management practices, their effect on cost of gain and ultimately, the producers bottom-line. In this day and age, it can be easier to add a supplement to increase intake or reduce metabolic disorders in the feedlot instead of understanding the origin of the problem. One of the most valuable managerial tools is understanding what controls intake and how intake variation affects the cattle performance and health. Variation in feed delivered can be easy to detect, but variations in DM proportions of a diet from unknown changes in moisture content of the feed is hard to detect unless ingredient DM are being taken and diet composition on as-fed basis modified to reflect changes in ingredient DM content. Ultimately, it is in the industries best interest to understand how variation in DM of feedstuffs affects performance of cattle through the feeding period.

Receiving Phase Health and Nutrition

Introduction

It is well understood that the receiving period remains the most challenging stage in feedlot cattle management. Newly received calves undergoing stress of weaning, marketing and transportation often express slow growth resulting from effects of handling and transportation, disease, and compromised intake during the first 4 weeks after arrival (Lofgreen, 1988). Although the most critical stage of the receiving phase is

the first 28 days after arrival, Samuelson et al. (2016) reported that receiving management has an effect on performance throughout the entire growing and finishing period.

Intake remains the greatest source of uncertainty in receiving management. By day 7 in the feedlot, 94.6% of healthy calves consume feed, but intake was between 0.5% and 1.5% of BW and only reaches 2% of BW until 14 days on feed (Hutcheson and Cole, 1986). Intakes less than 1% of body weight are below maintenance requirements (R. L. Preston, 2007) thus increasing the possibility for calves to develop an immune system challenge.

Preconditioning calves is recommended to aid in the transition of calves to the feedlot and its environment. Cole, (1985) defined preconditioning as a "management system designed to immunize calves against some major pathogens involved in the bovine respiratory disease complex and to reduce the stressors encountered in the feedlot." The author included in the review: for calves to be labeled as preconditioned, calves must be weaned 3 weeks prior to sale, trained to eat from a bunk or trough, treated for parasites, vaccinated for blackleg, malignant edema, Parainfluenza-3 virus, bovine viral diarrhea virus and *Haemophilus somnus*, castrated and dehorned, identified with an ear tag, sold through specific auctions and certified by a veterinarian. However, in a review published shortly after (Cole 1985), preconditioning was determined not accepted as a universal method to aid in reducing weaning and market stress (Lofgreen, 1988). Lofgreen (1988) indicated that due to a lack of uniformity in preconditioning practices, results of preconditioning on cattle health and performance was variable. Based on 10 studies focusing on receiving and preconditioning calf performance, calves which were

limit-fed creep feed had the same gain at the ranch, less shipping shrink, better feedlot gain and feed conversion (Cole, 1985). Although preconditioned calves had higher feed intake and gain during the receiving period (Lofgreen, 1988), calves which were weaned at shipment tended to gain more or at same rate as preconditioned calves due to compensatory gain (Cole, 1985; Lofgreen and Kiesling, 1985; Lofgreen 1988). Greater intake advantage by preconditioned calves was attributed to their learning to eat out of a bunk prior to arrival at the feedlot.

Depressed intake upon arrival at the feedlot has been the subject of much research. It is standard practice within the industry to offer long-stem hay upon arrival to teach calves to eat from a bunk. Yet, stressed calves had greater intakes when fed diets containing 1.2 Mcal NEg/kg than those fed 1.0 Mcal NEg/kg (Lofgreen, 1988). Generally, gain response is greater for calves started on diets containing 1.0 Mcal NE/kg diet DM than for those started on all hay diets as those fed all hay diets did not gain weight (Lofgreen, 1988). Adequate nutrition during the receiving period is needed to support weight gains and required to prevent morbidity during this time. Although cattle perform better on high-energy diets, morbidity and mortality tends to increase as diet energy increases (Lofgreen, 1988). Once cattle are recovered from the initial stressors, their intake increases rapidly; for those fed high-energy diets, this intake response may lead to ruminal acidosis compromising the immune system, making them susceptible to a bovine respiratory disease incident (BRD).

Bovine respiratory disease is the major cause of morbidity and mortality in the feedlot (Fulton et al., 2002; Rivera, et al., 2005; Snowder et al., 2002; Hay et al., 2016) contributing to 70% of death loss in the United States (Galyean et al., 1999). Controlling

the prevalence of BRD in the feedlot remains one of the biggest challenges in the receiving period. The complexity of the disease contributes to the challenge of preventing it. Stress, disease load and poor nutrition, resulting from poor diet quality before arrival or poor intake since arrival, all contribute to BRD occurrence. Stress arises from weaning, castration and dehorning and transportation. Snowder et al., (2002) completed a 15-year study (from 1987 to 2001) regarding environmental, genetic and economic factors on bovine respiratory disease in the feedlot. Author's stated due to castration, steers are at greater risk of BRD; 20% incidence of BRD in steers and only 14 % in heifers.

Stress from marketing and transportation reduced appetite and caused cattle to lose body weight (Hutcheson and Cole, 1986). As stated before, a major challenge associated with newly received cattle starting them on feed. Hutchenson and Cole (1986) reported by day 7, only 70% of morbid calves may be consuming feed exacerbating severity of BRD, decreasing feedlot performance thus increasing the importance good receiving management protocols.

Direct-Fed Microbials

In response to consumer pressure, use of feed grade antibiotics became regulated under the Veterinary Feed Directive (Food and Drug Administration, 2015). This action sparked interest to find reliable and effective alternatives to antibiotics. Research to understand mechanisms of action and effects of orally administered probiotics and prebiotics is now a priority.

Use of probiotics and non-antibiotics in the receiving phase represent alternatives that have demonstrated potential to replace the use of feed grade antibiotics. Probiotics

may be effective in manipulating the rumen environment for nutritional management purposes (Fuller, 1989). Rumen and gut microflora, which is developed at birth and reflective of an individual's environment (Fuller, 1989), are characteristic to each species. The microbial environment contributes to GI and immune function of the host (Gaggía et. al., 2010). Gut microbial population is generally stable; however, it is subject to be modified by excessive hygiene, antibiotic therapy and stress (Fuller, 1989).

Antibiotic therapy to maintain cattle health in response to stressors like weaning and transportation, and secondarily to enhance animal performance has been widely used; in some instances, perhaps abused. Fuller (1989) described probiotics as “a live microbial feed supplement which beneficially affects the host animal by improving its intestinal microbial balance”. However, the term probiotic is rarely used in animal production as the US Food and Drug Adminsitration coined the term direct-fed microbial (DFM) to replace the word “probiotic” when labeling feed additives containing live microbes (Khan et al., 2016).

Yoon and Stern (1995) summarized results of research with direct fed microbials and reported DFMs are utilized to aid in feed preservation, improve feed efficiency, milk production, body weight gain, and have been explored as a means to replace or reduce the use of antibiotics. Interest exists in supplementing bacterial, fungal or a blend of both to increase animal production. The most common DFM are comprised of bacterial organisms and are classified as either lactic acid-producing (LAB) or lactic acid-utilizing bacteria (LAU). Lactic acid-producing bacteria function to facilitate growth of rumen microorganisms adapted to acidic environments; they are often used in preservation of ensiled feed. Lactic acid producing bacteria stimulate lactic acid-utilizing bacteria growth

by promoting LAB to grow and produce lactate. *Enterococcus sp.*, *Streptococcus sp.*, *Lactobacillus sp.*, and *Pediococcus sp.* are the main LAB used in cattle production (McAllister et al., 2011). Supplementation of *L. acidophilus* led to greater milk production in dairy cows, and greater ADG and improved feed conversion efficiency calves and steers fed high-concentrate diets (Yoon and Stern, 1995). Elam et al. (2003), studied effects of feeding two strains of *L. acidophilus* or one strain of *P. freudenreichii* on performance, carcass and intestinal characteristics in feedlot cattle. In two experiments using feeder calves or calves that had been backgrounded of similar initial BW feeding either DFM seemed to improve ADG and tended to improved feed efficiency only in calves fed longer.

Research on *Megasphaera elsdenii,* the main LAU, maintained ruminal pH, prevented lactate accumulation and reduced the occurrence of acidosis (Elghandour et al., 2015; Kung, 2006). *Megasphaera elsdenii* shifted lactate and volatile fatty acid (VFA) production away from acetate and propionate production towards butyrate and valerate production (Kung, 2006). However, Kung (2006) also concluded that the optimum dosage and timing of administration of *M. elsdenii* for the use in high-concentrate feedlot diets and diets of high producing dairy cows is in need of development.

For bacterial species to prevail in the rumen, growth rate must exceed that of its disappearance and that of other bacterial populations of the rumen (Mackie and Gilchrist, 1979). During transitional periods, including weaning and the change from low to high concentrate diets, microbial populations are unstable (Savage, 1977). Adaptation of prevailing ruminal bacteria population from cellulolytic to amylolytic bacteria concentration disturbed the rumen environment leading to increased risk of metabolic

disorders (Mackie and Gilchrist 1979). Authors observed the LAB and LAU population of the rumen to stabilize 21 days after a dietary change from a forage-based diet to a diet containing grain and molasses collectively at 71% (DM basis). Supplementing LAU and LAB has the potential to shorten the lag phase during the shift in microbial population; this may translate in improved animal health and feed conversion efficiency, and greater BW gain.

Mode of action

Dosage, feeding frequency and time, and bacteria strain are factors contributing to bacterial VFA response (Elghandour et al., 2015). In a review completed by Krehbiel et al., (2003) authors attributed variation in responses of bacterial DFM in ruminants to a lack of understanding of their mechanisms of action.

Mode of action of bacterial DFM may be in the rumen or gastrointestinal tract (Fuller, 1989). LAB and LAU not only maintain ruminal pH but inhibit the binding and establishment of E. Coli and Salmonella in the gastrointestinal tract (Firon et al., 1983). Under growth pressure by beneficial bacteria, pathogenic bacteria are inhibited from establishment due to competition for attachment sites and nutrients (Kung, 2006).

Bacterial DFM synthesize antimicrobial bacteriocins (McAllister et al., 2011) and hydrogen peroxide (Dicks and Botes, 2010). Hydrogen peroxide blocked glycolysis through oxidation of sulfhydryl groups in metabolic enzymes associated with glucose transport, glyceraldehyde-3-phosphate dehydrogenase activity and hexokinase activity (Dicks and Botes, 2010). However, the bactericidal activity of hydrogen peroxide exhibited in vitro may not be present in vivo due to the limited oxygen concentration in the rumen (Krehbiel et al., 2003). Bacteriocins are ribosomally synthesized antimicrobial

peptides and proteins able to inhibit gram negative and positive bacteria through competition, membrane permeabilization and inhibition of cell wall synthesis (McAllister et al., 2011).

Additionally, bacterial DFM have increased immune responses by affecting the humoral (increased IgA and sIgA), cellular (changes in cytokine production) or nonspecific immune (phagocytosis of pathogens) response, singularly or jointly, as outlined in a review by Erickson and Hubbard (2000). Probiotics were taken up by epithelial cells through transcytosis and be engulfed by dendritic cells or macrophages; this resulted in or modified cells signals which resulted in cell development, and enhanced innate, humoral and cellular response by the immune system (Perdigon et al., 1995; Marin et al., 1998; Neumann et al., 1998)

Fungal

Yeast is the prevalent fungi used as an additive in ruminant production and is primarily supplemented dead and referred to as a yeast culture (Yoon and Stern, 1995). The accepted definition of a yeast culture is "a dry product composed of yeast and the media it was grown on, and dried in a manner to preserve the fermentation capacity of the yeast" (Yoon and Stern, 1995). Of these cultures, the culture derived from growing *Saccharomyces cerevisiae* is used extensively given positive responses by beef and dairy cattle fed this culture. However, production responses due to yeast supplementation have only occurred in situations where animals could benefit from an increase in protein synthesis or fiber digestion due to issues with the diet or managerial practices (Newbold, 1996). Shifts in ruminal fermentation may be as a result of yeast cultures themselves

providing nutrients including organic acids, B vitamins and amino acids to help feed the rumen microbial population (Robinson and Erasmus, 2009).

Aspergillus oryzae, another fungal culture commonly used in ruminants, is more diverse; this may explain variable responses observed when supplemented to calves, feeders and lactating cows (Yoon and Stern, 1995). In this review, authors discussed supplemented fungi selectively influence specific ruminal bacteria thus increasing microbial protein synthesis, altering amino acid profiles and potentially supplying limiting amino acids essential to high-producing animals. Increased microbial synthesis could explain the increased production response to yeast supplementation by cattle fed high concentrate diets and by cows in early or peak lactation. Multiple studies (Harris et al., 1983; Huber et al., 1985; Hoyos et al., 1987; Gomez-Alarcon et al., 1988; Erdman and Sharma, 1989; Harris and Webb, 1990; Williams et al., 1991; Wohlt et al., 1991; Higginbotham et al., 1993; Sievert et al., 1993) have reported greater milk yield, and greater milk protein and fat content from dairy cows supplemented with either *S. cerevisiae* or *A. Oryzae.* Because rumen microbial populations are unique to each animal, animals are expected to respond differently to feeding DFM. Therefore, there is a need to understand DFM mode of actions if they are expected to replace antibiotic use in the feedlot.

Backgrounding Cattle and Nutrition

Introduction

Since the United States Department of Agriculture (USDA) started recording in 1867, cattle inventory peaked in 1975 at 132 million head (*USDA-NASS*, 2016). The latest inventory of cattle (*USDA-NASS*, 2016) revealed the largest cattle population in the

last four years at 92 million head. In contrast, in the last three cattle cycles beginning in 1979, the USDA-NASS (2016) reported successively greater cattle inventory decline than expansion, yet, during these cycles there was a general increase in total pounds of beef produced.

Increases in beef production are attributed to greater finished and dressed weight from 2014 to 2015 (USDA-NASS, 2016). A proportion of increased beef production may be attributed to effects of improved genetics; however, methods and technology applied to cattle feeding permitted the industry to capitalize on cattle's genetic potential and, in turn, resulted in greater finished weights.

Growth of an animal, as described by Owens et al. (1995), is the accretion of protein, fat and bone, and is measured as a unit of mass or weight. Growth during the feeding period adds weight and makes feeding cattle profitable. Of these three body components, protein gain remains the most desirable, but is limited by maturity. Maximum body size, although dictated by genetics, can be altered positively or negatively by nutrition, hormonal status, and environment. (Owens et al., 1993). Maturity was defined as when body protein accretion plateaus; typically, at a body fat content between 34% and 37% of mature body weight (Owens et al., 1995). When this limit is reached, protein accretion is significantly reduced if not ceased and further weight gain is in the form of fat deposition.

Efforts to prolong protein accretion and maturation include use of technologies such as growth-promoting implants and growth management adjustments, which limit energy intake prior to finishing. Owens et al. (1995) reported that fat deposition proceeded quadratically while protein accretion followed a linear trend to weight gain.

This led the authors to conclude that under energy intake restriction and at adequate protein intake, fat deposition would be hindered permitting protein deposition to continue, thereby delaying maturity and increasing mature body size.

After a period of energy restriction, after cattle are adapted to ad-libitum feed intake growth responses is greater than that of cattle which did not experience an energy restriction (Bohman, 1954). This phenomenon, referred to as compensatory gain, was originally documented in cows and calves grazing pasture regrowth (Drouillard and Kuhl, 1999) and is extensively implemented in the feedlot where it is referred to as a backgrounding or grower phase (Cox-O'neill et al., 2017; Owens et al.,1993). This phase is implemented between weaning and the high-energy finishing phase. Using this strategy adds marketing flexibility to cow/calf producers or feedlot owners trying to capitalize on a specific market (Owens et al., 1993).

There are various ways compensatory gain is achieved: cattle in the grower or backgrounding phase are managed through grazing pastures or crop residues with protein or energy supplementation, fed high-forage diets or fed high-energy diets at restricted intake. Reuter and Beck, (2013) concluded after reviewing several studies in which yearlings were fed restricted energy intake since weaning and then permitted to consume high-energy diets ad-libitum, demonstrated greater DMI, ADG and HCW relative to those of calves placed directly in the feedlot after weaning. A confounding effect of experiments wherein a backgrounding period is used results from placing older and heavier cattle on high-energy finishing diets. Therefore, it is difficult to separate whether growth response to energy restriction and age and BW (Reuter and Beck, 2013).

A major advantage of backgrounding cattle results from management flexibility to meet the demands of the packer and consumer through increases in mature weight and carcass lean weight (Owens et al., 1993). Comparison of carcass traits by calves placed on a finishing diet from weaning or those placed on a finishing diet after a backgrounding phase revealed conflicting results pertaining to fat depth, marbling and KPH between the two feeding systems (Cox-O'Neill et al., 2017; Fox et al., 1972; Reuter and Beck, 2013). Fox et al. (1972) conducted two 2 x 2 x 2 factorial studies to understand effects of plane of nutrition (restricted or unrestricted), energy source (corn-based high-energy diets or soy bran flake-based medium-energy diets) and two slaughter weight endpoints (364 kg or 454 kg). Cattle, which were restricted to maintain a consistent body weight, were fed for either 190 d or 154 d in study 1 and 2, respectively, and were then fed a corn cob-based diet with either corn grain or soy bran flake (SBF) until they reached their designated slaughter weight. When the endpoint was 364 kg, Fox et al., (1972) reported significantly less empty body fat and more empty body protein steers that had been restricted. However, when finished at 454 kg, there was no difference in empty body composition. Restricting cattle improved conversions of digestibly protein and decreased PUN thus, increasing lean mass of the carcass which resulted in increased feed efficiency for cattle fed both corn and SFB until 364 kg. These results agree with Nour and Thonney, (1987) who concluded cattle finishing with larger mature size (small framed Angus vs Holstein) are more efficient at depositing protein from high energy diets than cattle of a smaller frame, but similar weight.

Fox et al., (1972) concluded that limit-fed cattle utilized energy more efficiently, but required more days on feed. These conclusions align with those of Coleman and

Evans, (1986) which attributed results of compensatory gain to enhanced metabolic efficiencies occurring post absorption.

Dietary substrate

Although results from several investigations demonstrated that cattle are more feed efficient when restricted for a period of time (Drouillard and Kuhl, 1999; Fox et al., 1972; Reuter and Beck, 2013), evidence from other research work was presented in which cattle did not fully compensate after a period of energy restriction (Coleman and Evans, 1986). Contrasting results were attributed to length of restriction, restricting cattle that are too young , and the nutrient (carbohydrates vs. protein) being restricted (Bohman, 1954; Fox et al., 1972; Drouillard, et al., 1991).

Drouillard et al. (1991) evaluated the effects of NE and metabolizable protein (MP) on compensatory gain. One hundred-sixty calves were stratified by weight and randomly assigned to eight treatments. Cattle were either restricted in NE or MP to 0.23 kg/d or 0.45 kg/d for 77 d or restricted 0.23kg/d for 154 d. These treatments were compared against two control groups, which were fed either a finishing diet or a balanced growing diet for 154 d followed by a finishing diet. Gains for cattle under feed restriction were targeted to achieve 0.23 kg/d or 0.45 kg/d. When cattle were fed diets containing limited metabolizable protein or energy after a 77 d period, gains did not differ. However, feed conversion efficiency during the finishing phase was enhanced by energy but not metabolizable protein restriction. Their theory for these results are based upon the importance of protein in the body through its role in energy metabolism and the possibility of an increased protein requirement to help replenish the bodies reserves if

protein restriction is too severe. Drouillard et al. (1991) also explained the challenge in accurately predicting growth when metabolizable protein is first limiting.

Backgrounding methods are dependent on climate and geography of the region. Although harsh winter conditions limit grazing through the winter months in the Midwest, forages such as silage and crop residue offer opportunity to background calves on these feeds. Over the course of two years, Cox-O'Neill et al. (2017) used 715 (335 in yr 1 and 360 in yr 2) spring born calves to determine effects of three backgrounding systems: grazing corn residue with dried distillers grains supplementation, grazing paddocks where oat, turnip and radish mix were planted as cover crop or fed a corn silage-based diet in a drylot. Authors reported ADG was greater (yr 2) for those backgrounded using the cover crop and residue treatments ($P < 0.01$), but steers fed in a drylot system had improved feed efficiency over the cover crop and residue treatment for both years ($P < 0.01$).

Over 40 years ago, grain was incorporated into feedlot diets as it increased the energetic density of diets, improved feed efficiency, and shortened cattle DOF compared to cattle finished on strictly forage diets (Huntington, 1997). Corn is the most utilized grain in feeding cattle (Samuelson et al., 2016). However, during times of high corn prices when it is more economical to sell corn, producers are in search of a dietary energy substitute to replace corn in the backgrounding phase.

Fermentation of carbohydrates provides energy in the form of ATP which in turn supports microbial growth and provides protein for the animal (Sutton, 1971). As stated in a review (Mary Beth Hall, 2010), sugars are both non-fiber and nonstructural carbohydrates found within the cell contents and are not included in the NDF portion.

Sucrose, a disaccharide composed of glucose and fructose, can be found in greater amounts in forages than mature grains where sugar is mostly converted to starch (Mary Beth Hall, 2010). Sugars are a highly digestible energy source due to their rapid fermentation in the rumen (Vallimont et al., 2004). However, this rapid fermentation, may result in negative effects on rumen environment and fermentation.

Rumen pH can alter VFA production through the modification of complex and unpredictable interactions between the substrate and microbial population (Sutton, 1971). Ruminal pH decreased faster and to a greater extent ($P < 0.05$) for cattle supplemented 1.0 kg/d sucrose in a diet consisting of grass silage, barley, and rapeseed meal (Khalili and Huhtanen, 1991). Total concentration of VFA were not affected by dietary treatment. However, molar production of butyrate and valerate were increased with sucrose supplementation whereas acetate was increased in control cattle supplemented starch (Khalili and Huhtanen, 1991). Author's (Khalili and Huhtanen, 1991) reported when sucrose was supplemented with sodium bicarbonate (0.25kg/d), pH was similar to cattle not supplemented sucrose (6.24 vs 6.28, respectively). When sodium bicarbonate was supplemented with sucrose, molar proportions of acetate increased and butyrate and valerate decreased compared to cattle only supplemented with sucrose. Vallimont et al., (2004) used a continuous culture fermenting system to understand changes in nutrient digestibility when sucrose replaced starch. Treatments included 7.5% starch and 0% sugar; 5.0% starch and 2.5% sucrose; 2.5% starch and 5.0% sucrose; and 0% starch, 7.5% sucrose. Unlike results of Khalili and Huhtanen, (1991), authors reported replacing sucrose with starch did not affect ruminal pH. However, total VFA concentrations were similar between treatments, despite a linear and quadratic decrease in the acetate:

propionate ratio of cattle fed sucrose which agrees with the findings of Khalili and Huhtanen, (1991). Authors (Vallimont et al., 2004) also reported a linear and quadratic increase in butyrate concentration as sugar replaced starch in a continuous culture fermenter system. Authors concluded, supplementing sucrose alters rumen fermentation, due to the changes in VFA proportions post-feeding.

Epithelial metabolism of fermentation products have reported to be affected by butyrate concentration (Storm et al., 2011). Oba et al., (2014) used 6 multiparous, non-lactating, ruminally cannulated dairy cows to determine short term effects of ruminal doses of starch and sucrose on rumen fermentation of gene expression of the ruminal epithelial. Treatments included supplementation of starch and lactose at 2.85 kg and 3.00 kg of DM. For the first hour post substrate dosing, average ruminal pH was similar between treatments, but pH dropped for the next 60 min for cows fed sucrose. Similarly, between 60 to 180 mins after supplementation, total VFA concentration was greater due to the increase in propionate and butyrate for cattle supplemented sucrose despite the decrease in acetate production compared to starch. After 30 mins of supplementation, molar levels of Butyrate were greater for sucrose supplemented cows than starch, resulting in increased NHE mRNA within the rumen papillae. Due to the increase in NHE mRNA, authors concluded cows fed sucrose were experiencing enhanced fermentation as NHE H^+ and NA^+ transporters have been linked to increased VFA absorption through simple diffusion (Oba et al., 2015).

Past research findings have reported mixed results pertaining to sucrose supplement and DM digestibility (Khalili and Huhtanen, 1991; Vallimont et al., 2004; Broderick and Radloff, 2010). DM digestibility was similar across treatments as sucrose

replaced up to 7.5% starch (Vallimont et al., 2004). However, NDF digestibility was improved for cattle supplemented 7.5% sucrose compared to 2.5 % and 5 % sucrose which authors explained as a result of a shift in the rumen microbial population. Khalili and Huhtanen, (1991) reported increased OM digestibility but, only when sodium bicarbonate was supplemented with sucrose. Variable results in DM digestibility responses to supplemental sucrose were explained in two study completed by (Broderick and Radloff, 2010). In study 1, DM, OM, NDF and ADF digestibility increased linearly as sucrose, in the form of dried molasses, was substituted for starch at 4%, 8% and 12% of the diet. However, in study 2, there was a cubic response for increased DM, OM, NDF and ADF digestibility as sucrose was supplemented, using liquid molasses, at 3%, 6%, and 9% of the diet. Authors attributed the variation in results between studies to CP levels of the basal diets. Study 1 diet contained 18% CP whereas study 2 contained only 15% CP. Therefore in study 1, possible responses to microbial growth in response to sugar supplement would not have been restricted by RDP (Broderick and Radloff, 2010). When ruminal carbohydrate and protein fermentation are not in synchrony, the fermentation of energy may not be adequate to capture all protein (Kim et al., 1999)

Broderick and Radloff, (2010) reported a quadratic trend for ammonia N to decrease up to 6% sucrose inclusion and excreted urinary N to be lowest at 4% sugar supplementation suggesting improved N utilization until 4% sugar supplementation. McCormick et al., (2001) reported similar findings as there was a tendency for sucrose supplemented at 5% to decrease rumen ammonia nitrogen inferring optimum carbohydrate and protein degradation rates resulting in increased microbial protein production (Mccormick et al., 2001; Broderick and Radloff, 2010). However, Vallimont

et al., (2004) reported similar ammonia N across treatments and explained these results could be due to sucrose utilizers in a continuous culture fermenter environment storing sucrose as polysaccharides to maintain the microbial population after feeding due to low levels of starch. Khalili and Huhtanen, (1991) reported a net loss of N for cattle fed the control and a small net gain in N when sugar was supplemented inferring the control diet did not provide sufficient energy to capture all silage N in the rumen.

Supplementing sugar to lactating dairy cows decreased acetate: propionate ratio, and increased butyrate production resulting in increased microbial protein production and milk production (Khalili and Huhtanen, 1991; McCormick et al., 2001; Vallimont et al., 2004; Broderick and Radloff, 2010). McCormick et al., (2001) supplemented 5% brown sugar food product to thirty-two multiparous lactating Holstein cows grazing ryegrass pastures for 56 d. However, DMI, milk yield, fat, protein, BW, BCS, NE_l were comparable between cows supplemented 0 and 5% brown sugar food product. Similarly Cherney et al., (2003) used 20 lactating Holstein cows to determine how changes in NFC levels and replacing 3% of high moisture corn with sucrose will effect milk production and composition. Authors (Cherney et al., 2003) reported no difference in milk yield, DMI, feed efficiency, milk fat, protein. Milk urea nitrogen was increased with sucrose supplementation and nitrogen retention was greater for cattle supplemented with 3% sucrose. Authors attributed this decrease in N utilization to the possibility of sucrose leaving the rumen and being absorbed in the small intestines before fermentation as it is very soluble carbohydrate (Hoover and Webster, 2001). Thus, shorting the rumen of energy needed for microbial protein, resulting in higher MUN and decreased N retention. Linear, quadratic and cubic responses were reported for DMI, milk production, and

protein yield for cattle supplemented 0%, 2.5% 5.0% and 7.5% sucrose (Broderick and Radloff, 2010). Authors reported optimum sugar inclusion varied based on performance parameter measured (yield, microbial growth, and nutrient digestibility) but, concluded 5% sugar inclusion which maximized milk yield to be optimum as it that is most economically advantageous (Broderick and Radloff, 2010). In an effort to lessen the negative energy balance state of transition cows, sugar was supplemented for starch to understand its effect on DMI, milk production and blood metabolites of peripartum dairy cows (Ordway et al., 2002). Treatments included a control with no sugar supplementation or were supplemented 2.7% sugar (DM bias; Domino pure granulated sugar) and fed 30 d prepartum until calving. Control diet contained 21.8 % starch and 6.6 % sugar from dietary ingredients and the treatment diet contained 20.4 % starch and 8.8 % total sugar. No treatment effect was observed on prepartum or postpartum DMI. Authors explained dissimilar DMI between their results and past research as a result of differences in type and quality of forages. Prepartum glucose was elevated for cows fed sucrose, however there was no effect on DMI, milk production or milk components either pre- or postpartum. Cows supplemented with sucrose treatment had less difficulty calving as measured using calving difficulty scores. Ketosis was less prevalent in cows supplemented with 2.7% sugar (4 treatments vs 1, respectively, which could be attributed to increased blood glucose prepartum, however, authors urged more research to be done in this area before drawing hard conclusions (Ordway et al., 2001).

Sucrose in the form of molasses have been utilized as in the feedlot industry to serve as a carrier for ionophores, NPN, and minerals (Felix et al., 2018). Pervious research pertaining to sucrose has entailed supplementing sucrose in an effort to increase

the digestibility of low-quality forages fed to dairy and beef cows. Excess nitrogen from alfalfa hay has the opportunity to be utilized for MCP when molasses is supplemented Heinemann and Hanks, (1977). Heldt et al. (1999) reported increased digestibility of poor-quality forages resulting from an increase in total organic matter intake with supplements containing RDP and sugar supplementation in rumen cannulated steers.

Molasses became a feed for livestock in 1885 in order to increase sugar beet production and avoid the European sugar crisis (Ware, 1902). Since then, research has been conducted to understand optimum molasses inclusion in finishing diets. Heinemann and Hanks, (1977) used 54 yearling Hereford and crossbred steers to determine if substituting 9.6% and 14.4% cane molasses for a barley beet pulp mix would affect growth and carcass performance. Cattle were fed for 146 d and molasses was delivered in a wheel feeder. Cattle supplemented 14.4% molasses had decreased daily gain compared to cattle supplemented 0% or 9.6% molasses. DMI was similar between treatments, resulting in increased feed efficiency of control and 9.6% supplemental sugar group. Authors attributed this loss in feed efficiency to the decrease in net energy of blackstrap molasses which was found to decrease from 1.58 M cal/kg to 0.833 Mcal/kg when fed at 10% and 23% of a diet (Lofgreen and Otazaki, 1960).

In a more recent study, Felix et al., (2018) conducted an study to determine the optimum inclusion of sucrose of cattle fed high concentrate rations. Cattle were fed a similar basal diet consisting of 20% corn silage, 55.5% dry-rolled corn, 20% modified wet distillers grains with solubles and 4.5% dry vitamin/mineral supplement. Treatments included 0% supplemental sugar, 4.5%, 9% and 13.5% liquid supplement, where liquid supplement directly replaced corn. Supplementing sucrose for 194 d had no effect on

DMI, ADG, and feed efficiency. Steers supplemented 4.5% and 9% liquid supplement had similar final BW and calculated NE_m and NE_g, but were greater than those of cattle fed 13.5% liquid supplement. Authors also stated there was no advantage in supplementing liquid above 13.5%. This conclusion agrees with previous work completed by Emanuele et al., (2015) which reported optimum sugar inclusion of 6.75% when starch was between 20% and 25% of the diet. Positive results in milk yield from supplementing molasses in high forage dairy diets and no adverse effects on feedlot and carcass performance in the finishing phase generated sufficient interest to study the optimum inclusion of molasses in the backgrounding phase particularly as a substitute energy source when corn grain price is high.

Finishing Phase Nutritional Management

Introduction

Dr. Pritchard can be quoted (1993) stating 'cattle do not know how to eat' and he bases this hypothesis on the fact that founder and acidosis would not exist if they did. He follows these remarks with conclusions stating it is a feedlot manager's role to teach cattle how to eat to avoid these metabolic issues. However, issues in understanding what drives intake, how we measure it and how to control variation in intake creates a challenge for feedlot managers to successfully achieve a constant DMI.

Fluctuation in DMI has shown to alter feed efficiency and reduce growth performance (Galyean, et al., 1992). Stock et al., (1995) calculated animal intake variance (AIV), the variation in daily intake residuals for an individual animal within a specified time, and reported AIV was negatively ($r = -.28$) correlated with feed efficiency. Resulting decreases in feed efficiency are often associated with the occurrence of

subacute and acute acidosis and bloat (Fulton et al., 1979; Owens et al., 1997) which account for 21% of sudden deaths during the feeding period (Pierson et al., 1976). Although, intake fluctuation many not always hinder rumen health to the point of subacute or acute acidosis (Owens et al., 1997). Chronic acidosis has been declared at a ruminal pH of 5.6 and acute when ruminal pH reaches 5.2 (Cooper et al, 1999). To understand intake fluctuations and their impact on acidosis, a series of metabolism studies were completed (Cooper et al., 1999). Area of ruminal pH under 5.6 was increased for cattle fed at 80% of their calculated ad-libitum intake, with imposed daily intake variations of 1.4 kg/d, but not at 0.7 kg/d. Thus, inferring the occurrence of chronic acidosis and decreased feed efficiency at intake variations of 1.4 kg/d. A 10 % loss in feed efficiency costs a producer a loss of $26/hd (Pritchard, 1993). This economic loss from decreased efficiency and the potential for sudden deaths are what drive feedlot producers to decrease variability in intake through the feeding period. Two major areas in which error can occur resulting in daily intake variation are in feed delivery and ration mixing (accuracy).

Variation in feed delivery and bunk management

Variations in intake can occur individually and by pen, but it is unclear to what extent the two are related (Pritchard and Bruns, 2003). Uncertainties in determining pen intake stem from the perception of a intake as feed delivered and the assumption that feed delivered was consumed among all cattle on an average bases in a 24 h period (Gibb and McAllister, 1999; Pritchard and Bruns, 2003). However, this assumption in DMI of individuals is flawed as 7% to 18% of cattle may not be seen at the feed bunk in a 24 h period (Hicks et al.,1989). None the less, cattle are not fed individually resulting in feed

delivery calls being made on a pen basis. Thus, increasing the risk of erratic changes in intake, feed waste and metabolic issues, consequently decreasing feed efficiency and increasing feed cost per gain (Pritchard, 1993). In an effort to reduce variation in intake, the idea of managing bunks was developed to help producers understand and explain losses in gain through the prevention of cyclical intake patterns. Prior to the removal of forage and increase of grain in finishing diets, forage served as the bunk manager, by limiting intake due to gut fill while also stabilizing the rumen (Pritchard, 1993). However, as authors stated in this same review, it was this removal of forage from finishing diets that caused a need to develop and implement good bunk management practices to control the sudden increase in metabolic disorders. Bunk management is defined as 'matching the amount of feed delivered to the amount of feed cattle can handle' (Pritchard, 1993). In order to achieve this, a numerical bunk scoring system was developed in conjunction with the push for recording and maintaining consistent feed deliveries and feeding times. The bunk scoring system is a numerical system between 0 and 4 in which a score of 0 is no feed remaining in the bunk; 0.5 is scattered feed but most of the bunk is exposed; 1 is a thin uniform layer of feed across the bottom of the bunk typically 1 kernel deep; 2 is 25 to 50% of feed is remaining; 3 the crown of feed is thoroughly disturbed with greater than 50% of feed remaining; and 4 is when the feed is untouched (Pritchard, 1993). To effectively use this system, the author stresses bunk calls to be made at the same time every day in order to accurately make feed calls and reduce intake variation (Pritchard, 1993). As cattle enter the finishing phase, intake regulation is changed from greater physical regulation to metabolic regulation due to higher energy diets containing less forage (Baile and McLaughlin, 1987). Feedlot operators stepping

cattle up on feed to fast in an effort to maximizing intake and performance can put cattle over the edge and cause a cyclical intake pattern (Pritchard and Bruns, 2003). Pritchard's bunk management system (1993) recommends allowing 2 to 3 days of a clean bunk (bunk score 0) to allow cattle to transition to new intakes and avoid backing off feed.

Ad-libitum feeding had traditionally been the preferred method of feeding to maximize intake (Lawrence, 1998), but is affected greatly with environmental conditions, management factors, cattle type and dietary factors resulting in varied effects on performance (NRC, 1996). Large fluctuations in intake and increased cost of gain associated with this feeding strategy brought about the idea of clean bunk management (Lawrence, 1998). To understand differences in cattle efficiency between these two feeding systems 6,000 hd of cattle were either fed ad-libitum or using a clean bunk management and observations were made and recorded for intake, performance and health of cattle. (Lawrence, 1998). Intake, gain and heath were similar between treatments, however feed waste was considerably greater, 7.5 tonnes vs 0.2 tonnes DM/study period, for cattle fed ad-lib vs clean bunk management, respectively. However, a similar designed study (Pritchard and Bruns, 2003) in which cattle were fed true ad-libitum vs managed bunks reported similar intakes, but reduced ADG (0.94 kg vs. 1.71 kg) and decreased feed efficiency (9.58 kg vs. 5.35 kg;) of ad-libitum fed cattle experiencing up to 9 kg/d fluctuations in day to day intakes.

Even with the use of bunk management, large variations in intake can still occur and variations in high concentrate diets are believed by many to be the leading cause of digestive disturbances (Galyean et al., 1992; Zinn, 1994; Gibb and McAllister, 1999; Pritchard and Bruns, 2003). The primary source of variation in the feedlot is due to

human error in feed delivered or feeding time (Pritchard, 1993). In 1992, Galyean et al., fed 108 crossbred steers over 84 d to understand the impact of 10% daily and weekly intake variation on cattle performance. Cattle were fed to gain 1.25 kg/d using a 90% concentrate diet. Authors reported varying intake by 10% daily decreased gain by approximately 7% but, varying weekly feed intake did not affect gain over the 84 d feeding period. A similar study was conducted (Soto-Navarro et al., 2000) in which daily fluctuations of 10% resulted in decreased ADG and feed efficiency by 7% for cattle fed to gain 1.25 kg/d during on a 90% concentrate diet for 84 d agreeing with the results reported by Galyean et al., (1992). Authors stated this decrease in performance associated with intake fluctuation can be attributed to either an 8% increase in ME requirement or a 4% decrease in diet NE_g value. To try and determine this, Zinn (1994) conducted a performance and metabolism study using Holstein steers late in the finishing phase and imposed fluctuations on daily feed intake by 20%. At 20% daily intake fluctuations there were no implications on performance, digestive function or NE_m of the diet. In another study completed by Soto-Novarr et al (2000), using 176 steers to understand 10% daily fluctuations in intake for cattle fed to gain 0.9 kg/d and 1.25kg/d. No difference in ADG or feed efficiency at either rate for gain was reported for the 84 d feeding period despite cattle fed fluctuating intakes to have greater ADG and feed efficiency between days 56 – 84 as compared to constant intake cattle. Authors suggest cattle fed consistent fluctuating intakes may adapt to this variation resulting in similar performance between treatments. This hypothesis also agrees with the data reported by Galyean et al., (1992) which showed the advantage in gain and feed efficiency to narrow as BW increased.

Similar research has been conducted to understand how variation in deliveries affects performance in ad-libitum fed cattle. Although cattle showed decreased gain and feed efficiency when feed delivery was fluctuated 10% (Gaylean et al 1992, Sotto-Norvvo et al 200), when cattle were imposed a 1.8 kg/d variation in feed delivery of a 93 % concentrate diet for at 140 d, there was no decrease in performance compared to steers fed consistent ad-libitum intakes (Cooper et al., 1999). Variable results in daily delivery variation data may be due to the possibility that as cattle reach their maximal level of intake, fluctuations in consumption may have a greater impact on metabolic status (Pritchard, 1998). Authors (Cooper et al., 1999) speculated intake variation may have allowed for steers to build a buffer capacity on low intake days to compensate on over consumption days. This theory agrees with previous research which reported as imposed intake variations increased (0.7 kg/d, 0.9 kg/d, 1.4 kg/d or 1.8 kg/d) on ad-libitum fed diets, area of ruminal pH below 5.6 decreased (Cooper et al., 1997).

Frequency of feed delivery, has the potential to either decrease intake variation by allowing a second or third delivery to correct mistakes or increase the risk of variation by increasing the opportunity to have error occur in mixing and loading rations. Soto-Navarro et al., (2000) completed two studies to understand how time of day and frequency of delivery and fluctuations in once or twice a day feeding affected performance. Authors reported delivery frequency and time of day had no effect on ADG, but feed efficiency tended to be greater than cattle fed 2 or 3 times a day as compared to those fed once daily. It was noted that although all treatment groups were feed to achieve the same DMI, those feed 2 or 3 times a day had greater DMI which authors (Soto-Navarro et al., 2000) associated this increase to the potential for greater

error related to weighting and delivering feed 2 to 3 times a day as compared to once daily. In the second study, Soto-Navarro et al., (2000) reported frequency of feeding and daily intake fluctuations do not affect ADG or feed efficiency. Cattle adapt to high concentrate diets by eating smaller more frequent meals (Fulton et al., 1979) therefore, feeding frequency may not alter eating behavior and cattle may adapt to consistent fluctuations in intake (Gibbs and McAlister, 1999).

Ration integrity accuracy

Careful consideration is taken when formulating rations to insure nutrient requirements are met for growing and finishing cattle. However, human error can change these formulations during loading and mixing, in turn creating variation in diets and decreasing performance of cattle. Research (Wagner et al., 1988) using 72 growing heifers to compare two feeding systems of the scale and mixer to the 'front end loader and scoop shovel method'. Authors reported for growing heifers, DMI ADG and feed efficiency were increased by 2.7%, 10.3 % and 11.8%, respectively, for cattle fed using a scale and mixer compared to cattle fed by volume and assumptions. In 1988, authors reported it would take 130 hd on feed for 133 days a year to pay for and operate a mixer wagon. Inconsistency of feed in the bunk results in cattle consuming different diets resulting in variation in gain and feed efficiency and flesh of cattle in a pen (Pritchard, 1993). Since the Wagner research, feeding cattle using a mixer and scale have become basic management practices, however they have not eliminated loading errors. Sova et al., (2013) completed a study in which 22 commercial dairies were used to determine the degree in TMR deliveries varied from the formulated ration, and how this variation changed nutrient characteristics, milk yield and milk characteristics. Authors reported on

average, delivered mixed diets did not represent their formulation with all nutrient components having > 5% CV except DM, CP, TDN and NE_L. Most variable between fed and formulated was in higher priced feed stuffs such as Ca, Na and trace minerals. However, day-to-day variation in the mixed diets across dairies was lower than variation between fed and formulated diets.

Inaccuracy in mixing diets can arise due to issues that can be easily addressed such as lazy employees, broken scale head or problems with mixing equipment, however, there are variables that attribute to this inaccuracy that can be challenging to measure and prevent. First, the opportunity for variation to occur in mixed diets will always be present as diets are formulated on a DM basis, but mixed and delivered on an as-fed basis (Mcbeth et al., 2013; Weiss et al., 2012), therefore encouraging producers to minimize to prevent manageable variation parameters. One parameter in particular being the variation in nutrient composition of feed ingredients which can not only affect diet formulation, but the economic value of the feed and productivity of cattle (Weiss et al., 2012). Authors stated current practices are to formulate rations to a greater nutrient content if ingredients to be used are highly variable in a specific nutrient. In this report, Weiss et al., (2012), explained if the requirement is 16% CP but, the source of protein in the diet is dried distillers grains with solubles (DDGs) which has a history of being highly variable, nutritionist may formulate the ration to contain 17% CP to reduce the risk of feeding a diet deficient in CP. However, over supplementing for a nutrient is not always economically feasible. Therefore, authors wanted to determine the variability in nutrient composition of feedstuff used on well-managed dairy farms across the US. A total of 49 dairies were used in the study in which nutritionist sampled major ingredients used in the

high group lactation diets monthly. The effect of an ingredient on the variation observed in the TMR is dependent on variation in the ingredients nutrient composition and its inclusion rate in the diet (Weiss et al., 2012). Corn silage was one of the most variable feedstuffs with coefficients of variation (CV) of 9.5, 6.2 for starch and NDF, respectively. Dried distillers grains (DDGS), is known to nutritionist to be highly variable, however this data shows high moisture corn (HMC) to be more variable (CV = 7.2) than DDGs (CV = 3.4) in CP. Eight farms collected feed samples daily for 14 d to help grasp day to day variation of nutrient compositions (Weiss et al., 2012). Corn silage had an average range in starch of 12.2 percentage units with the best farms ranging only 6.3 and the most variable varying 27.7 units. Although authors noted these values could be skewed due to sampling or laboratory error, if silage varied 27 units at 25% of the diet (DM basis), starch concentration would very 3.5 units which could negatively affect the rumen (Weiss et al., 2012). Although understanding nutrient composition of feedstuffs is critical to maximize cattle performance, the cost associated with analyzing samples and the lag time between sampling, mailing, samples being analyzed, results shared with the nutritionist and finally the nutritionist updating the ration, the nutrient composition of the feedstuffs have most likely changed again.

Understanding dry matter of ingredients is also critical in the effort to control variation in DMI. A major issue with the front-end loader scoop shovel is the method is it uses ingredient volume to determine quantity of the ingredient to be fed (Wagner et al., 1988), which can result in tremendous variation due to changes in DM delivered particularly in high silage diets (Wagner et al., 1988). Day to day silage DM ranged within farms from 5.1 percentage units to 10.4 percentage units (Weiss et al., 2012)

which could alter diet composition. Which agrees with other research where corn silage DM was reported to have day to day variation of 6.7 (Mcbeth et al., 2013). Feed DM cannot only vary day to day from precipitation on exposed feed, but also on the timing of harvest of feedstuffs. Average annual rainfall in Minnesota is 81.38 cm. During peak harvest in September and October, average rain falls are 8.31 cm and 7.39 cm, respectively (U.S climate data, 2019), which can cause harvest of crops to be completed over many days, resulting in varying DM content of feed as it is being stored. In an effort to understand how changes in ingredient DM can effect lactating dairy cows, Mcbeth et al., (2013) used 24 Holstein cows and implemented two, 3 day bouts of 10% DM fluctuation of alfalfa and corn silages over 21 d. Treatments were control (no changes in silage DM), unbalanced (UNBAL) treatment which fed wetted silages, but ad-fed inclusions were not changed to accommodate the change in DM and balanced (BAL) treatment in which cows were fed wetted silages but as-fed diets were adjusted so that the forage: concentrate ratio was the same as the control diet. Silages were sampled daily to avoid any unexpected change in silage DM. Average DM of the three treatment diets were 66.2%, 63.9% and 60.7% for control UNBAL and BAL treatments, respectively. Mean 21d DMI did not differ between control and UNBAL or BAL treatment cows however, day to day variation in intake was greater for BAL cows than control cows. Authors explained the lack of an effect on DMI could be attributed to the fact that cows were fed the same diets for 15 out of the 21 d. As-fed intakes for both UNBAL and BAL cows were increased on day 2 of the wet silage feeding and this increase in as-fed intake remained until 1 day after cattle were changed back to the control. Authors explained this response was due to the gastrointestinal tract being partially full of the previous days diet

or a delayed recognition by the animal of the change in diet DM. Milk production was increased for the UNBAL compared to the control cows due to increased NE_L as a result of NDF being replaced with starch (lower F:C ratio compared to control or BAL treatments). With slight changes in fatty acid digestibility and organic matter digestion suggesting slight changes in normal rumen function of cows fed ether the UNBAL or BAL treatments (Mcbeth et al., 2013).

Unlike analyzing feed stuffs for nutrients, testing feed DM is less expensive and can be done on farm. Oetzel et al., (1992) compared on farm drying methods to the laboratory drying standard to understand the most accurate and time effective systems. Methods tested were a microwave oven, conventional forced air oven (otherwise referred to as a Koster tester), and a commercial electronic moister tester which were all compared to the standard in which samples were dried for 48 h at 100 ^{o}C in a commercial drying oven. Samples tested were alfalfa silage, corn silage, and high moisture whole shelled corn (HMSC). Microwave and Koster overestimated DM for corn silage, but only Koster was significantly different ($P < 0.05$). Electric moister tester was inconsistent in determining corn silage and authors stated the need for calibration for specific forages to accurately measure them using this tester. However, the electric moister tester was the most accurate for determining the DM of HMSC as compared to the microwave and Koster tester that over dried the corn. The microwave method, where each feedstuff have various protocols required the most time and attention as compared to the Koster tester and electronic moister tester (Oetzel et al., 1992). Authors concluded each system has its place when determining DM of specific feedstuffs, but producers should choose one

based on operator ease and success each system has in drying the dietary ingredients that are used on their farm.

Most research to date conducted to best understand how fluctuations in DMI affect cattle performance have been done using controlled, implemented variations. Therefore, there is a need to understand how natural daily changes in ingredient DM affected DMI performance of cattle.

CHAPTER II

EFFECTS OF BLENDED MICROBIAL FEED ADDITIVES ON RECEIVING CATTLE PERFORMANCE AND HEALTH

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SYNOPSIS

Weaning and transit negatively affect DMI of newly received cattle. Restoring DMI is imperative to ensure rapid recovery and adequate response to immunological challenges. Eubiotics have the potential to increase DMI. The objective of this study was to evaluate effects of feeding a pre- and probiotic blend or a DFM-prebiotic blend on health and performance response by newly received crossbred cattle. Ninety-two Angus crossbred (Ranch 1) steers (n = 60; average BW = 271 $\pm$ 12 kg) and heifers (n = 32; Average BW = 245 $\pm$ 14 kg) and 89 Red Angus crossbred (Ranch 2) steers (average BW = 263 $\pm$ 10 kg), weaned immediately before trucking 1,520 km to the feedlot, were randomly allocated (5 to 7 hd/pen) within ranch and sex to one of 15 pens in each of two (north or south side) locations within a deep bedded confinement barn. Cattle were fed once daily for 49 d, orts were collected and weighed prior to feeding. Additives were incorporated daily into the total mixed ration as a premix using dried distillers grains. Performance data were analyzed using the MIXED procedure of SAS with pen and sex as random effects. Morbidity data were analyzed using PROC GLIMMIX of SAS. By day 7, cattle fed either additive tended ($P < 0.10$) to have greater DMI; this effect did not persist past 7 d. Cattle fed either microbial blend had heavier BW and ADG ($P < 0.003$) at day 28 and 49, which led to greater feed conversion efficiency ($P < 0.03$). Fewer ($P = 0.001$) cattle fed microbial blends were treated for BRD. Feeding either the prebiotic/probiotic blend or a DFM-prebiotic blend reduced morbidity and improved cattle performance during a 49-d receiving period.

Keywords: Eubiotics, Health, Nutrition

INTRODUCTION

Cattle experience a tremendous amount of stress from numerous factors during the receiving period. Weaning, marketing, transportation, handling procedures, new environment, and disease exposure contribute to depressed appetite (Lofgreen, 1988), decreased intake (Preston, 2007), and poor growth response (Hutcheson and Cole, 1986). Furthermore, these stressors in conjunction with exposure to viral and bacterial agents are known to increase the risk of bovine respiratory disease (BRD; Duff and Galyean, 2007). Fulton et al., (2002) observed calves treated once for BRD returned $40.64 less per head than those not treated. Metaphylaxis antibiotic treatment either administered as a feed grade antibiotic or injectable have been previously used to control BRD prevalence in the feedlot. However, since the Food and Drug Administration modified guidance for a Veterinary Feed Directive to encompass feed grade antibiotics typically used to mitigate BRD, the feedlot industry is search of new tools to reduce its prevalence. Feed additives, including enzymes, direct-fed microbials (DFM), prebiotics, probiotics and phytogenics have shown positive evidence to help improve animal health and performance. Research encompassing the supplementation of DFM in Holstein calves resulted in improved ADG, feed efficiency and reduced incidence of diarrhea (Seo et al., 2010). Newbold (1996) reported that feeding yeast increased BW in calves, ADG of adult cattle and milk yields of lactating cows. Furthermore, enzymes and feed additives with probiotic or prebiotic activity have proven to restore gut populations in stressed cattle enabling them to return to normal function (Newbold, 1996). Therefore, our objective was to evaluate the effects of feeding a pre-and probiotic blend (PRE-PRO) and a DFM and prebiotic blend (DFM-PRE) additive on performance and health based on feed efficiency and

prevalence of illness. We hypothesized feeding either blend would improve health and performance of crossbred cattle in a 49-d receiving period.

MATERIALS AND METHODS

All animal handling and procedures were approved by the Institute of Animal Care and Use Committee at the University of Minnesota. Steers and heifers utilized in this study were housed in facilities located at the University of Minnesota Beef Research and Teaching Farm in Rosemount, MN.

Animals, receiving and heath protocol

Ninety-two Angus crossbred (ranch 1) steers (n = 60; 271 $\pm$ 12 kg BW) and heifers (n = 32; 245 $\pm$ 14 kg BW), and 89 Red Angus crossbred (Ranch 2) steers (263 $\pm$ 10 kg BW) were weaned and transported (1,518 km; 19 h ranch one, 27 h ranch two) to the University of Minnesota beef research and teaching facilities (Rosemount, MN) in October of 2017.

Upon arrival, animals were individually weighed (XR5000; Tru-Test, Mineral Wells, TX) prior to accessing feed and water, administered an infectious bovine rhinotracheitis, parainfluenza$_3$, bovine respiratory syncytial virus intranasal vaccine (INFORCE 3 Zoetis, Inc. Parsippany, NJ), infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza$_3$, bovine respiratory syncytial virus modified live vaccine, *Mannheimia haemolytica – Pasteurella multocida* bacterin-toxoid (Titanium 5 + PH-M, Elanco Animal Health, Greenfield, IN), and an intramuscular *Clostridium (C.) chauvoeis, C. septicum, C. haemolyticum, C. novyi, C.sordellii, C.perfringens* Types C and D bacterin-toxoid (Ultrabac 8, Zoetis , Inc. Parsippany, NJ). Cattle were also given injectable minerals (Multi-Min USA, Fort Collins, CO), anthelmintic pour-on (Dectomax

Pour-on, Zoetis Animal Health, Parsippany, NJ), tagged with a visual and electronic identification tag and rectal temperature measured to determine if antibiotic treatment (flunixin meglumine; Resflor Gold, Merck Animal Health, Madison, NJ) was required (temperatures > 39.7° C indicated the need for antibiotic treatment).

Revaccination occurred 7 days post-arrival and initial vaccination. Cattle were weighed prior to feed being delivered and administered an intramuscular infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza$_3$, bovine respiratory syncytial virus modified live vaccine (Titanium 5, Elanco Animal Health, Greenfield, IN), and dewormed using a fenbendazole oral drench (Safe-Guard, Merck Animal Health, Madison, NJ). At this time, an extended release implant (200 mg trenbolone acetate and 28 mg estradiol benzoate; Synovex One Feedlot, Zoetis Animal Health, Parsippany, NJ) was administered. Cattle were weighed individually on day 1, 7, 28, and 49 prior to feeding. Final weight (49 d) was recorded after removing feed and water for 16 h.

Calves were treated when displaying rectal temperatures > 39.7° C during times of processing or upon display of BRD symptoms (lethargic, labored breathing, nasal discharge, gaunt). Pen checks were conducted once daily by personnel blinded to treatment. Calves displaying symptoms listed with a rectal temperature below 39.7° C received respiratory disease treatment at the discretion of personnel blinded to treatment. Cattle requiring treatment, were initially treated with florfenicol and flunixin meglumine (Resflor Gold, Merck Animal Health, Madison, NJ). If symptoms persisted and/or temperature remained unchanged, animals were retreated using enrofloxacin injectable for cattle (Baytril 100, Bayer, Shawnee Mission, KS). No animals required a third treatment.

Cattle were randomly allocated (5 to 7 hd per pen), within ranch and sex, to one of 15 pens in a deep-bedded confinement barn after cattle were received as explained previously. Pen rows were contained north or south of a 6.7 m feed alley; each row contained each block (ranch and sex). Pens measured 3 m wide by 9 m deep. A continuous bunk line was separated between each pen by a solid metal divider to prevent feed from being shared between pens. Each pen had 3 m of bunk space allowing for 60 to 42 cm of bunk space per head. Each pen contained a heated, automatic water tank (Omni 1, Ritchie Industries Inc., Conrad IA).

Diets and treatments

Pens, within blocks, (ranch or ranch and sex) were randomly allocated to one of three dietary treatments; Control (corn-gluten feed), pre-probiotic blend (PRE-PRO) or DFM and prebiotic blend (DFM-PRE). A basal diet was formulated (Table 1) and treatments were incorporated (0.11 kg/hd/day) at 5% of the diet (DM basis) in the form of a distillers grains and solubles-based premix that was blended daily by hand. Cattle were fed once daily at 0700 h for 49 d. Feed ingredients were loaded in a vertical mixer (Patz 270, Patz Corp., Pound, WI) in the order of: hay, corn silage, dried distillers grains (DDGs), additive premix, and liquid supplement. Each treatment was fed in one load in the order of control, PRE-PRO and DFM-PRE. The feed mixer was completely emptied between each treatment load and a non-treatment load was mixed last to ensure no treatment residue remained in the mixer for the control diet the following day. Feed deliveries were based on bunk calls (0, slick bunk to 4, 100% feed remaining) wherein a bunk call of 0 for 2 consecutive days resulted in an increased DM offering of 0.22 kg/hd. Bunk calls at or greater than a score of 1 elicited a reduction in DM offered equivalent to

2.5%, 5%, 10% or 20% of previous day's delivery, when bunk scores were 1, 2, 3 or 4, respectively.

Data collection and analysis

Feed ingredient samples and feed refusals (orts) were collected weekly and stored at -20° C until laboratory analysis was conducted Orts were weighed and sampled when feed remaining in the bunk appeared to be more than 0.45 kg DM. Prior to nutrient analysis, all feed samples and orts were dried (Blue M, Thermal Product Solutions, New Columbia, PA) at 60° C for 48 h to calculate DM of sample and ground using a Model 4, Thomas-Wiley Laboratory Mill, (Thomas Scientific, Swedesboro, NJ) to pass through a 1 mm screen. Samples were analyzed in duplicate for crude protein (CP; Method 992.15; AOAC, 1995), neutral detergent fiber (NDF; Van Soest et al., 1991), and ether extract (EE; Method 920.39; AOAC, 2000). Crude protein analysis was completed using a 2300 Kjeltec Analyzer Unit (FOSS Analytical, Foss Allé 1 DK-3400 Hilleroed, Denmark) where samples were digested in 10 mL of sulfuric acid and 1 kjeltab for 1 h at 410 ^{o}C prior to being analyzed for nitrogen content. Neutral detergent fiber was analyzed using an Ankom 200 Fiber Analyzer (Ankom Technology, Macedon, NY), in which samples were extracted at 100^{o} C for 1 h using heat stable α-amylase. Prior to extraction, samples containing greater than 5% EE (Corn silage, DDGs, dry rolled corn and orts) were extracted (Bremer et al., 2010) to insure all EE was dissolved during the NDF procedure to ensure accurate NDF determination. Ether extract concentration was analyzed using an Ankom^{XT10} extraction system in which samples were extracted for 90 min at 90^{o} C with petroleum ether.

Statistical analysis

Statistical analyses of performance data were performed using the MIXED procedure of SAS version 9.4 (SAS Institute Inc, Cary, NC) using a generalized randomized block design. Pen was used as experimental unit. Variables of interests were initial, 7 d, 28 d and final BW, ADG, DMI and feed efficiency. Model to test effects of treatment and block on dependent variables contained terms for treatment (τ), block (β; random) and sex:

$$Y_{ijk} = \mu + \tau_i + \beta_j + Sex_k + \varepsilon_{ijk}$$

Random effects of barn location (confounded with ranch source) and sex were included if it reduced Akaike's Information Criteria (AIC). Feed efficiency was analyzed as the response by ADG to treatment effects using DMI as a covariate in the model; least square means of feed-to-gain ratio (with no *P*-values) is provided for ease of interpretation. Contrasts were performed for both performance and morbidity data to separate differences between the two additives and additives and control. Significance was declared if *P* was less than or equal to 0.05 and tendencies were discussed between 0.05 and 0.10. Morbidity data (total treated animals) were analyzed using GLIMMIX procedure of SAS.

RESULTS AND DISCUSSION

Interim cattle performance

After 7 d on feed, cattle receiving the DFM-PRE treatment had greater DMI (*P* = 0.02) than those receiving PRE-PRO, and cattle fed either additive tended (*P* = 0.10) to

have greater DMI than control cattle (Table 2). Cattle fed either additive had greater ADG ($P < 0.01$) than control cattle through day 7 (Table 2). This resulted in greater feed efficiency ($P = 0.01$). However, cattle fed both additives had similar ADG and feed efficiency ($P > 0.30$) by 7 d on feed.

Effect of feeding either additive on DMI was not present after 28 d ($P = 0.83$; Table 3). After 28 d, cattle supplemented with either additive had improved ($P = 0.007$) feed efficiency resulting from greater ($P = 0.01$) ADG compared to cattle not supplemented. In addition, there was a tendency ($P = 0.09$) for cattle fed DFM-PRE to have greater ADG than those fed PRE-PRO through 28 d. At the end of 28 d, supplementing either additive resulted in greater ($P = 0.02$) BW compared to those not supplemented an additive. Our results agree with those of Kenney (2013) who reported a cubic response in ADG after 28 d of a receiving period for cattle supplemented with a DFM consisting primarily of *Lactobacillus acidophilus* and *Enterococcus* and rumen degradable protein (RDP) between 80% and 120% of requirement, respectively. Gill et al., 1987 reported a 9% improvement in gain and a 19.5% increase in feed efficiency when a bacterial DFM was supplemented for 28 d to receiving cattle. Krehbiel et al. (2003) concluded that gain response to DFM supplementation early in the feeding period may be due to DFM aiding a compromised immune system.

Cumulative performance

As listed in Table 4, over the entire 49-d receiving period, DMI was not different ($P > 0.07$) across the three treatments which is in agreement with previous findings (Krehbiel et al., 2001; Elam et al., 2003; Vasconcelos et al., 2008; Kenney, 2013; Dick, 2017). Cattle supplemented with either additive responded with greater ($P = 0.003$) ADG

compared to those fed no additive. However, only cattle supplemented with DFM-PRE had greater (P =0.01) feed efficiency than those fed no additive. At the conclusion of the 49-d receiving period, cattle supplemented with either additive had greater (P = 0.003) final shrunk BW compared to those not supplemented with an additive. Galyean et al. (2000) reported increased ADG and final BW when supplementing *Lactobacillus acidophilus* and *Propionibacterium freudenreichii* to cattle fed a high concentrate diet. However, Vasconcelos et al. (2008) reported no increase in BW or ADG, but reported a positive quadratic response in feed efficiency for cattle supplemented increasing concentrations of *Lactobacillus acidophilus* and *Propionibacterium freudenreichii*. Vasconcelos et al. (2008) were not able to provide an explanation for this quadratic response.

Contrary to our findings, numerous studies have reported no changes in performance of receiving or finishing cattle when supplemented with a DFM (Krehbiel et al., 2001; Elam et al., 2003; Dick, 2017). Cattle used in the present study were weaned and transported 1,518 km (19 h or 24 h) to the research facilities in Rosemount MN. Studies where no differences in growth performance between supplemented and control groups were noted used cattle that were primarily from local or less distant sale barns. This observation led us to believe that stress associated with extended periods of feed or water depravation and/or long hauling may cause greater stress on calves than occurs in calves experiencing short-distance transport. Hutcheson and Cole (1986) stated in a review that during transit, cattle lose more shrink than fasting alone, inferring greater tissue losses.

Greater gain response with no change in DMI, as observed in the present study, supports the idea (Krehbiel et al., 2003) that DFM may increase energy utilization of feed. Cattle supplemented with *Megasphaera elsdenii* had greater ruminal concentration of butyrate and valerate (Kung, 2006). These two VFAs are associated with greater VFA absorption (Oba et al., 2015) or as substrate for bacterial protein synthesis (Oba et al., 2015), respectively.

Cattle health

No mortalities were reported in the 49-d feeding period, and morbidity results are presented in Table 5. Cattle supplemented with either additive remained healthier than those not supplemented for the duration of the study. Incidence of respiratory disease in cattle fed no additive was 21%; yet, only 5% or 3% of cattle fed PRE-PRO and DFM-PRE, respectively, were treated during the 49-d feeding period. These observations agree with those of Gill et al (1987) who reported a 10% reduction in morbidity in calves fed a bacterial DFM. However, Kenney (2013) reported no difference in morbidity between calves fed a primary *Lactobacillus acidophilus* and *Enterococcus faecium* DFM blend and those fed no DFM supplement. Calves in the study by Kenney (2013) were raised locally and likely were subject to less stress. Lower morbidity by calves fed DFM could be attributed to probiotics being taken up by epithelial cells, and engulfed by dendritic cells (Dicks and Botes, 2010) resulting in enhanced innate, humoral and cellular response of the immune system (Perdigon et al., 1995; Marin et al., 1998; Neumann et al., 1998).

SUMMARY

In the present study, feeding either additive improved ($P < 0.03$) ADG which resulted in greater weights ($P < 0.003$) for cattle fed either additive. Because there was no

effect of feeding either additive on DMI, feed efficiency of cattle fed either additive was greater. Over the 49-d receiving period, supplementing either additive at the inclusion rate of 0.11 kg/hd/day reduced ($P < 0.001$) morbidity compared with those not supplemented with an additive. Therefore, it is concluded feeding either a prebiotic/probiotic blend or a DFM/prebiotic blend reduced morbidity and improved cattle performance during a 49-d receiving period compared to cattle not fed an additive.

Table 1. Dietary ingredient composition resulting from each daily load and dry matter content measured weekly, and nutrient composition of diets corrected for feed refused

Item, %	Control	PRE-PRO	DFM - PRE
Dietary ingredient	----------DM basis----------		
Corn silage	41.45	41.55	41.37
Hay [a]	23.38	23.28	23.33
DDGs [b]	13.61	13.55	13.69
DRC [c]	10.72	10.75	10.75
Additive premix [d]	5.90	5.92	5.86
Supplement [e]	4.95	4.95	4.99
Nutrient Composition			
DM	54.59	54.54	54.66
CP	12.59	12.73	12.60
NDF	32.24	29.40	32.24
Ether extract	3.77	3.78	2.46
NEm, Mcal/kg	1.65	1.65	1.65
NEg, Mcal/kg	1.07	1.07	1.07

[a] Dry ground intermediate wheat straw grass mix
[b] Dried distillers grains with solubles (Big River Resources Boyceville LLC, Boyceville, WI)
[c] Dry rolled corn
[d] Premix was mixed daily by hand to include 0.11 kg/hd of each treatment using DDGs as the carrier.
[e] Supplement formulated to contain 200 mg/kg lasalocid Bovatec, Zoetis Animal Health, Parsippany, NJ).

Table 2. Growth performance of cattle supplemented with either corn gluten feed (control), PRE – PRO and DFM-PRE for 7 d

	Treatment				Contrast	
Item	Control	PRE-PRO	DFM - PRE	SEM	PRE - PRO vs DFM-PRE	Control vs Additive
Pens, *n*	10	10	10			
In BW, kg [a]	251	258	258	26	0.93	0.19
DMI, kg/d	2.69	2.70	2.87	0.20	0.02	0.10
ADG, kg	0.80	1.20	1.41	0.31	0.30	0.007
ADG at same DMI, kg [b]	0.51	0.98	1.21	0.23	0.34	0.01
Feed:gain, kg/kg	2.86	1.17	0.98			
d 7 BW, kg [c]	256	265	267	29	0.03	0.77

[a] In BW recorded on arrival with 19 or 28 h without feed or water
[b] F:G kg/kg listed as a reference, however, feed efficiency was analyzed as the effect of treatment on ADG using DMI as a covariate
[c] BW recorded prior to morning feeding

Table 3. Growth performance of cattle supplemented with either corn gluten feed (control), PRE – PRO and DFM-PRE for 28 d

	Treatment				Contrast	
Item	Control	PRE-PRO	DFM - PRE	SEM	PRE - PRO vs DFM-PRE	Control vs Additive
Pens, *n*	10	10	10			
d 7 BW, kg [a]	256	265	267	29	0.03	0.77
DMI, kg/d	4.78	4.74	4.87	0.39	0.34	0.83
ADG, kg	1.32	1.45	1.62	0.21	0.09	0.01
ADG at same DMI, kg [b]	1.26	1.48	1.58	0.02	0.10	0.003
Feed:gain, kg/kg	3.92	3.51	3.14			
d 28 BW, kg [c]	288	298	302	29	0.43	0.02

[a] Recorded weight at 7 d prior to morning feeding
[b] F:G kg/kg listed as a reference, however, feed efficiency was analyzed as the effect of treatment on ADG using DMI as a covariate
[c] BW recorded prior to morning feeding

Table 4. Growth performance of cattle supplemented with either corn gluten feed, PRE – PRO and DFM-PRE for 49 d

	Treatment				Contrast	
Item	Control	PRE-PRO	DFM - PRE	SEM	PRE - PRO vs DFM-PRE	Control vs Additive
Pens, *n*	10	10	10			
In BW, kg [a]	251	258	258	26	0.93	0.19
DMI, kg/d	5.75	6.02	5.98	0.49	0.81	0.07
ADG, kg	1.32	1.47	1.55	0.21	0.25	0.003
ADG at same DMI, kg [b]	1.30	1.41	1.51	0.02	0.14	0.02
Feed:gain, kg/kg [b]	4.71	4.30	4.01			
End BW, kg	315	328	332	30	0.49	0.003

[a] Initial BW recorded on arrival with 19 or 28 h without feed or water
[b] F:G kg/kg listed as a reference, however, feed efficiency was analyzed as the effect of treatment on ADG using DMI as a covariate
[c] End BW recorded after withdrawing feed and water for 16 h

Table 5. Morbidity [a] in cattle supplemented corn gluten feed (control), PRE-PRO or DFM-PRE for 49 d

	Treatment				Contrast	
Item	Control	PRE-PRO	DFM - PRE	SEM	PRE - PRO vs DFM-PRE	Control vs Additive
Pens, *n*	61	60	61			
Treatments, n [b]	13 (21%)	3 (5%)	2 (3%)	0.65	0.65	0.001

[a] No mortality.

[b] value corresponds to total treatments (first and retreatments) per dietary treatment. Values in parentheses represented percentages of total treatments out of all animals within dietary treatment group.

CHAPTER III

OPTIMIZING SUGAR INCLUSION IN HIGH-ROUGHAGE DIETS FOR GROWING CATTLE

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SYNOPSIS

The objective of this study was to determine optimum sugar concentration based on daily gain and feed conversion of growing cattle fed high-forage diets. Ninety-two Angus crossbred (Ranch 1) steers (n = 60; 339 + 11 kg BW) and heifers (n = 32; 309 + 14 kg BW), and 89 Red Angus crossbred (Ranch 2) steers (338 + 16 kg BW) were allocated randomly (5 to 7 hd/pen), within ranch and sex, to one of 15 pens in each of two (north or south side) locations within a deep-bedded confinement feedlot. Dietary treatments were designed to contain supplemental sugar inclusion of 0%, 3.5%, 7% or 10.5% (DM basis) using a molasses-based supplement containing 56.8% sugar and 7.4% urea. Diets were comprised (DM basis) of hay (12%), corn silage, dry distillers grains (14.5%), dry rolled corn and a liquid supplement (5%). Corn grain and corn silage inclusion varied from 21% to 32% and from 29% to 36%, respectively, to remove a portion of dietary starch to accommodate supplemental sugar. This resulted in dietary sugar concentrations of 4.3%, 7.4%, 10.5% and 13.5% or 0%, 3.5%, 7.1%, and 10.6%, respectively, as supplemental sugar. Energy value of corn or test ingredient was derived from estimated dietary metabolizable energy (ME). This study was analyzed as completely randomized block design. Replacing from 0 to 10.6% of starch did not affect ($P > 0.38$) ADG. Substitution of up to 10.6% starch with sugar led to no differences ($P > 0.26$) in feed conversion efficiency (analyzed as ADG at the same DMI). Final BW was not affected ($P > 0.47$) by substituting up to 10.6% starch with sugar. Concentration of dietary ME calculated by iteration tended to decrease linearly ($P = 0.10$) as sugar replaced starch. Intake of ME was similar ($P > 0.10$) across treatments. Although numerically different, ME concentration of sugar, as it replaced starch, was similar to that

of corn grain. Concentration of ME at 3.5% sugar inclusion was greater ($P < 0.01$) than that at 10.5%, and tended ($P < 0.10$) to be greater than that at 7% sugar inclusion. Feeding up to 10.5% sugar resulted in no adverse effects on performance. Yet, the energy value of sugar is similar to that of corn grain when substituting up to 7% of starch in a growing diet.

Keywords: sugar, starch, backgrounding

INTRODUCTION

Backgrounding cattle on high-forage diets allows flexibility in growing and finishing systems while adding value to land, forage and cropping systems. However, because cow-calf producers are concentrated in areas with access to range, pasture and forage, backgrounding diets are often formulated based on hay or fermented forages (corn, small grains or grass silage).

Extent and length of energy restriction interact to determine performance, carcass weight and degree of marbling achieved during the ensuing finishing period. Johnson and DiCostanzo (2017) revealed that cattle fed to gain 0.9 to 1.04 kg/d for fewer than 100 d, by manipulating intake or limiting energy content of the diet to less than 1.14 Mcal NE_g/cwt had greater feed conversion efficiency in the feedlot and had greater carcass weight.

Sugar in liquid-based feed presents a versatile option to supply energy in regions where grain inclusion is costly and scarce. Research with 125-kg grass-silage-fed cattle demonstrated that feeding sucrose at 7.5% of dietary DM led to maximum ADG compared to those supplemented with 5%, 10% or 15% sucrose (England and Gill, 1985). Similarly, feeding 4.2 to 5.7% sugar as replacement for starch to fattening bulls led to gains and feed conversions similar to those when starch was not replaced (Boucque et al., 1976).

Optimum inclusion of sugar in high-forage diets fed to growing cattle has not been determined. Evidence from early research in growing cattle fed high-forage diets points to optimum responses to sugar feeding in the range of 4% to 9% of dietary DM (England and Gill, 1985; Boucque et al., 1976), which agrees with findings of Emanuele

et al. (2015) in lactating dairy cows. Therefore, the objective of this study was to determine the optimum sugar concentration in high-forage diets fed to growing cattle. We hypothesized that diets of backgrounding cattle containing from 31% to 34% starch and 3.5% to 7% sugar support similar gains and feed conversion as diets formulated with 37% starch and no sugar, and decreased gains and feed conversion with diets formulated to contain 27.5% starch and 10.5% sugar.

MATERIALS AND METHODS

All animal handling and procedures were approved by the Institute of Animal Care and Use Committee at the University of Minnesota. Steers and heifers utilized in this study were housed in facilities located at the University of Minnesota Beef Research and Teaching Unit in Rosemount, MN.

Animals, facilities and diet

Ninety-two Angus crossbred (Ranch 1) steers (n = 60; 339 + 11 kg BW) and heifers (n = 32; 309 + 14 kg BW), and 89 Red Angus crossbred (Ranch 2) steers (338 + 16 kg BW) were allocated randomly (5 to 7 hd/pen), within ranch and sex, to one of two 15-pen rows in a deep-bedded confinement barn. Pen rows were contained north or south of a 6.7 m feed alley; each row contained each block (ranch and sex). Pens measured 3 m wide by 9 m deep. A continuous bunk line was separated between each pen by a solid metal divider to prevent feed from being shared between pens. Each pen contained 3 m of bunk space allowing for 42-60 cm of bunk space per head. Each pen contained a heated, automatic water tank (Omni 1, Ritchie Industries Inc., Conrad, IA).

Cattle had been fed receiving dietary treatments consisting of supplementing diets with a pre- and probiotic, a direct-fed microbial and a prebiotic or a placebo (corn gluten

feed) in an study that lasted 49 d after arrival. At the end of that study, the population of each cattle pen was reconfigured, within ranch and sex, so that up to 33% of the resulting pen configuration was comprised of cattle that represented each of the treatments in the receiving period.

On arrival, prior to initiation of the study, cattle had received infectious bovine rhinotracheitis, parainfluenza$_3$, bovine respiratory syncytial virus intranasal vaccine (INFORCE 3 Zoetis, Inc. Parsippany, NJ), infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza$_3$, bovine respiratory syncytial virus modified live vaccine, *Mannheimia haemolytica – Pasteurella multocida* bacterin-toxoid (Titanium 5 + PH-M, Elanco Animal Health, Greenfield, IN), and an intramuscular *Clostridium (C.) chauvoeis, C. septicum, C. haemolyticum, C. novyi, C.sordellii, C.perfringens* Types C and D bacterin-toxoid (Ultrabac 8, Zoetis , Inc. Parsippany, NJ.) Cattle were also treated with injectable trace minerals (Multi-Min USA, Fort Collins, CO), dewormed (Dectomax Pour-on, Zoetis Animal Health, Parsippany, NJ), tagged with a visual and electronic identification tag, and rectal temperature measured to determine if antibiotic treatment was required (temperatures > 39.7° C indicating the need for antibiotic treatment). Within 14 d from the arrival procedure, cattle were revaccinated with an intramuscular infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza$_3$, bovine respiratory syncytial virus modified live vaccine (Titanium 5, Elanco Animal Health, Greenfield, IN), and dewormed using a fenbendazole oral drench (Safe-Guard, Merck Animal Health, Madison, NJ). Concurrently, rectal temperature was measured to determine if antibiotic treatment was required (temperatures > 39.7° C indicating the need for antibiotic treatment); at this time, an extended release implant (200 mg trenbolone acetate and 28

mg estradiol benzoate; Synovex-One Feedlot, Zoetis Animal Health, Parsippany, NJ) was administered.

Pens, within blocks, (ranch or ranch and sex) were assigned to one of four dietary treatments consisting of sugar supplementation at 0%, 3.5%, 7% or 10.5% (8, 7, 8 or 7 replicate pens in each treatment, respectively) of dietary DM to replace equal proportions of starch. Diets were comprised (DM basis) of hay (12%), corn silage, dry distillers grains (DDGS, 14.5%), dry rolled corn and a liquid supplement (5%); dietary corn grain and corn silage concentration varied from 21% to 32% and from 29% to 36%, respectively, to accommodate supplemental sugar substitution of starch. A molasses-based supplement (Westway Feed Products, Tomball, TX) containing 56.8% sugar and 7.4% urea was used to supplement sugar while providing additional non-protein nitrogen (NPN). Addition of urea to sugar supplement was deemed necessary to maintain synchrony between molasses and NPN (Bowman et al., 1995).

Cattle were fed once daily at 0700 h. Feed ingredients were loaded in a vertical mixer (Patz 270, Patz Corp., Pound, WI) in the following order: hay, corn silage, DDGS, dry rolled corn, liquid supplement and liquid molasses supplement. Feed offerings were made based on bunk calls (0, slick bunk, to 4, 100% feed in bunk) wherein 2 consecutive days with bunk calls of 0 resulted in increased DM offering (0.22 kg/head). Bunk calls at or greater than a score of 1 elicited a reduction in DM offer equivalent to 2.5%, 5%, 10% or 20% of previous day offer when bunk scores were 1, 2, 3, or 4, respectively.

Cattle were weighed after withdrawing feed and water for 16 h to determine initial and final BW. Otherwise, cattle were weighed every 28 d in the morning before

feeding. The study lasted 70 d; therefore, there were three interim weight periods; two were 28 d and one was 14 d.

Feed samples, nutrient composition and analysis

Feed ingredient samples and feed refusals (orts) were collected weekly and stored at -20° C until laboratory analysis could be performed. Orts were weighed and sampled when feed remaining in the bunk appeared to be more than 0.45 kg of DM. Prior to nutrient analysis, all feed samples and orts were dried using a drying oven (Blue M, Thermal Product Solutions, New Columbia, PA) at 60° C for 48 h and ground using a Model 4, Thomas-Wiley Laboratory Mill, (Thomas Scientific, Swedesboro, NJ) to pass through a 1mm screen. Feed ingredients and orts were then composited based on weighing period (feed ingredients) or the entire feeding period (orts). Samples were sent to Dairyland Laboratories (Arcadia, WI) to be analyzed in duplicate for CP (Method 990.03, AOAC 1995), NDF (Method 2002, 04, AOAC 2005), either extract (Method 920.39, (AOAC, 1995), starch (AOAC collaborative study,2019) and sugar (Extraction from Derias, 1961, detection procedure from Hall, 2000). Composite samples were made based on DM composition of loads mixed or feed refused. Dry matter intakes were calculated from DM offered and refused. Nutrient composition of dietary ingredients, sampled weekly and composited to represent each interim period, is listed in Table 1. Ingredient composition of diets (DM basis), representing the composite average of ingredients loaded daily in the mixer across the entire 70-d period, is listed in Table 2. Table 2 also depicts nutrient concentration of diets resulting from composite analysis of weekly feed ingredient samples offered (as described above) corrected for nutrient analysis of ort samples.

Iterative energy procedures

Energy concentration of the diet was calculated by using shrunk initial and final BW, resulting shrunk ADG and DMI. These values were used to iterate dietary ME concentration using NRC (2000) equations of energy requirements for maintenance and growth. The procedure used to determine a single feed ingredient (test ingredient) ME content is based on substitution; therefore, it required assumption of knowledge of ME content of each of the non-test ingredients. At zero sugar supplement inclusion, the test ingredient was corn grain while corn silage, DDGS, hay, and mineral supplement were ascribed 2.66, 2.69, 1.94 and 1.33 Mcal ME/kg DM, respectively, as estimated from calculations derived from laboratory analyses of each of these feeds. At 3.5%, 7% and 10.5% sugar supplementation, the test ingredient was the sugar supplement; ME content of non-test ingredients remained as listed above. Metabolizable energy content of corn grain in these substitutions was also derived from laboratory analysis (3.09 Mcal ME/kg DM). Metabolizable energy of corn grain (when no sugar was supplemented) or sugar supplement was estimated by subtracting the contribution of hay, corn silage, dried distillers grains and mineral supplement to ME intake (DMI of each ingredient and their respective ME concentration derived from laboratory analysis) from dietary ME intake. Concentration of ME of each test ingredient was obtained by dividing ME contribution to the diet by their respective intake. Crude protein (measured from weekly ingredient samples composited for each weigh period) composition of diets ranged from 13.6% to 17.1% (Table 2).

Statistical analysis.

The study was analyzed as a completely randomized block design blocked by ranch (or pen row) using Procedure Mixed of SAS (SAS 9.4, Cary, NC). Pen was the experimental unit. Variables of interest were initial and final weights, ADG, DMI, feed efficiency and corn grain or sugar supplement ME (ME value of test ingredient). The model to test effects of treatment and block on dependent variables contained terms for treatment (τ), block (β; random) and sex:

$$Y_{ijk} = \mu + \tau_i + \beta_j + Sex_k + \varepsilon_{ijk}$$

Initial BW was retained as a covariate if it was found to be significant ($P < 0.05$). Feed efficiency was analyzed as the response by ADG to treatment effects using DMI as a covariate in the model. This approach permits determination of effects of DMI (set constant by covariate analysis) on ADG. In the results section and tables, feed efficiency is expressed both as this variable and as least square means (with no *P*-values) of feed required per unit gain for ease of interpretation. Least square mean difference *P*-values were adjusted (Tukey) in the LSMESTIMATE statements of SAS. The statement LSMESTIMATE was used to generate orthogonal linear, quadratic and cubic polynomial contrasts. Statistical significance was declared when *P*-values were less than 0.05. Trends were discussed when *P*-values were greater than 0.05 but less than 0.10.

RESULTS AND DISCUSSION

Across diets, removal of portions of dietary corn silage and corn grain resulted in reductions of dietary starch content of 3.6%, 7.1% and 10.7%, respectively, for diets supplemented with 3.5%, 7% and 10.5% sugar. Across sugar supplementation treatments, on average, 24% corn silage and 76% of corn grain starch, respectively, was replaced. Inclusion of a sugar-based supplement resulted in nearly 100% substitution of starch; supplemental sugar content was 3.5%, 7.1% or 10.6%, respectively, for diets initially projected to be supplemented with 3.5%, 7% or 10.5% sugar. Total starch and sugar concentrations of each diet were 37.3% and 4.3%, 34.0% and 7.4%, 30.8% and 10.5%, and 27.6% and 13.5%, respectively, for diets supplemented with 0%, 3.5%, 7%, and 10.5% sugar (Table 2).

All diets provided sufficient amounts of rumen-degradable and metabolizable protein to meet requirements as determined from cattle weight and growth rate using the Beef Cattle Nutrient Requirements Model (NASEM, 2016). Inclusion of crude protein in the sugar supplement was indicated based on previous observations of cattle performance and digestibility response to sugar inclusion in diets (Bowman et al., 1995). Addition of rumen-degradable protein, an effect confounded with sugar inclusion, had no effect on DMI in the present study (Table 3). Total organic matter intake and digestibility increased linearly in response to rumen-degradable protein supplementation (Arroquy et al., 2004).

Growth performance

No linear, quadratic or cubic trends in DMI were observed ($P > 0.14$) in DMI when sugar was supplemented. We conclude, based on our observations and findings in

previous literature (McCormick et al., 2001; Ordway et al., 2002; Cherney et al., 2003; Oelker et al., 2008; Owens et al., 2008), DMI is not affected when sugar is supplemented for starch in high-forage diets. Ordway et al. (2002) proposed that sucrose supplementation is thought to stimulate DMI due to increased palatability of the diet; however, authors reported no change in DMI when supplementing 2.7% sucrose in prepartum and postpartum dairy cows, which agrees with observations from the current study. Similarly, cattle fed a finishing diet supplemented with molasses and glycerin or with a dry supplement containing 46% ground corn had similar DMI (Felix et al., 2018). Historically, molasses is utilized in the feedlot as a carrier to supply minerals, non-protein nitrogen (NPN), and ionophores suspended in liquid molasses. Molasses inclusion conditions diets, reducing sorting, increasing the consistency of the diet and maintains suspended additives (Heinemann and Hanks, 1977; Felix et al., 2018).

In a study designed to investigate effect of energy source on intake and digestibility, Heldt et al. (1999) reported greater forage OM and total OM intake by cattle provided ad-libitum access to low-quality tallgrass-prairie hay supplemented with starch (corn starch grits) or sucrose (Domino pure cane extra fine granulated sugar) at 0.30% BW/d compared to those not supplemented. However, there were no differences in total intake between cattle supplemented with sugar or starch. Similarly, in another study (McCormick et al., 2001) where cattle were fed a grass diet supplemented with a 5% brown sugar food product at 2.5% DM, intakes did not differ due to supplemental energy source compared to those not supplemented. However, a report does exist in which molasses inclusion affects DMI (Broderick and Radloff, 2004), wherein increasing sugar

concentration (0%, 4%, 8% and 12% DM basis) in diets of lactating dairy cows led to a positive linear DMI response.

Replacing from 3.5% to 10.6% of starch did not ($P > 0.38$) affect ADG (Table 3). Despite numerical differences (Table 3), substitution of up to 10.6% starch with sugar led to no differences ($P > 0.26$) in feed efficiency. Further, because of lack of difference in ADG ($P > 0.10$) across treatments, final BW was not affected ($P > 0.10$) by substituting up to 10.6% starch with sugar. We hypothesized that in diets with up to 7.5% sugar with 31% starch, gain and feed efficiency would be comparable to cattle fed diets containing 37% starch and no supplemental sugar. This was based on conclusions by Emanuele et al. (2015) who reported optimum sugar inclusion of 6.75% when dietary starch content is between 20% to 25% of the diet (DM basis). Similarly, in a lactating cow, milk yield, BW gain and final BW were similar up to 5% sugar supplementation (McCormick et al., 2001; Cherney et al., 2004). Comparable findings were reported when sugar was replaced starch in a cattle finishing study (Heinemann and Hanks, 1977; Felix et al., 2018). Feeding up to 9.6% sugar inclusion resulted in similar gains as those observed at 0% inclusion; however, feeding greater than 13.5% sugar and glycerin resulted in lower gain and feed conversion and reduced NE_m and NE_g estimated from performance (Heinemann and Hanks, 1977; Felix et al., 2018). Heinemann and Hanks (1977) attributed poorer feed conversion to the decrease in net energy of molasses when supplemented over 10%.

Concentration of dietary ME calculated by iteration tended to decrease linearly ($P = 0.10$) as sugar substituted starch (Table 3). Concentration of dietary ME at 10.5% sugar supplementation (2.59 Mcal/kg) agreed with that reported by Preston et al. (1969), which calculated dietary ME of 2.56 Mcal/kg when cane molasses was supplemented at 15% of

dietary DM. There is a possibility that added energetic burden resulting from excess protein, particularly degradable protein (Table 2), in the diet may have contributed to lower ME content of the diet iterated from performance (greater intake and less gain). At a cost of 1.2 Kcal/g of excess N intake as estimated by Reed et al. (2017), a differential of 374 g of excess protein between the treatment with no supplemented sugar and that with 10.5% supplemental sugar would yield an energetic cost (NE_m) of 539 Kcal daily (784 Mcal ME). Dividing this value by DMI reported for the treatment containing 10.5% sugar (9.28 kg; Table 3) results in a differential in ME concentration of 0.084 Mcal/kg which accounts for nearly 65% of the difference in ME concentration between the value iterated for the treatment with no sugar supplementation and that containing 10.5% sugar supplementation. However, due to numerically greater DMI, ME intake did not differ ($P > 0.10$) across treatments (Table 3). Figure 1 depicts ME concentration of dry rolled corn (at 0% supplemental sugar inclusion) or of sugar supplement at incremental inclusions between 3.5% and 10.5% of dietary DM. Substituting starch with sugar led to a quadratic response ($P = 0.03$) and a trend for a cubic response ($P = 0.09$; Figure 1) in metabolizable energy of dry rolled corn or sugar supplemented at 3.5%, 7% or 10.5% of dietary DM. Calculated concentration of ME of dry rolled corn is similar to that reported by NRC, 3.16 Mcal/kg vs 3.18 Mcal/kg respectively (NRC, 1996). Metabolizable energy of molasses was greater at 3.5% and 7% inclusion than reported by the NRC 3.83 Mcal/kg and 2.99 Mcal/kg vs 2.71 Mcal/kg, respectively (NRC, 1996). This could be explained through increased proportions of propionate and butyrate and decreased acetate measured at up to 7.5% sugar inclusion in grass silage-based and alfalfa silage- and corn silage-based diets (Khalili and Huhtanen, 1991; Vallimont et al., 2004). Additionally, the role of

butyrate on maintaining epithelial metabolism (Storm et al., 2011), and its effects on VFA absorption, particularly on increased propionate absorption (Oba et al., 2015) may help explain increased ME of sugar in the present study.

SUMMARY

In the present study, replacing up to 10.5% of starch with sugar led to no changes in intake or growth performance. Collectively, these results supported our hypothesis that diets of backgrounding cattle containing from 31% to 34% starch and 3.5% to 10.5% sugar yield similar gains and feed conversion as diets formulated with 37% starch and no sugar.

Table 1. Dry matter and nutrient concentration (%) of samples collected weekly and analyzed on the composite for each weigh period (two 28-d and one 14-d period)

Ingredient	DM	Starch	Sugar	CP	NDF	Ether extract
Hay [1]	83.3	0.3	4.9	5.5	76.3	2.0
Corn silage	35.2	40.6	1.6	7.7	33.4	4.2
DDGS [2]	91.6	3.2	8.6	28.6	35.0	8.1
DRC [3]	88.9	69.0	3.8	8.3	7.7	4.2
Sugar supplement [4]	63.5	0.63	56.8	29.1	0.83	0.85
Mineral supplement [5]	65.1	0.19	13.4	78.4	0.85	0.98

[1] Dry ground wheat straw grass mix
[2] Dried distillers grains with solubles (Big River Resources Boyceville LLC, Boyceville, WI)
[3] Dry rolled corn
[4] Supplement formulated to contain 56.8% sugar and 7.4% RDP (Westway Feed Products, Tomball, TX).
[5] Supplement formulated to contain 225 mg monensisn/hd/d (Rumensin, Elanco Animal Health, Greenfield, IN).

Table 2. Dietary ingredient composition resulting from each daily load and dry matter content measured weekly, and nutrient composition of diets corrected for feed refused

Item	0%	3.5%	7%	10.5%
Dietary ingredient	----------DM basis----------			
Corn silage	36.2	34.4	31.7	29.3
DRC [1]	32.1	27.9	24.4	20.6
DDGS [2]	14.6	14.5	14.5	14.5
Hay [3]	12.0	12.0	12.0	11.9
Sugar supplement [4]	0.0	6.2	12.5	18.6
Mineral supplement [5]	5.1	5.0	4.9	5.0
Nutrient composition				
DM	56.2	56.5	57.1	57.7
Starch	37.3	34.0	30.8	27.6
Sugar	4.3	7.4	10.5	13.5
Sugar from supplement	--	3.5	7.1	10.6
CP	13.6	14.7	15.9	17.1
NDF	28.9	28.0	27.0	26.0
Ether extract	4.1	3.9	3.7	3.6
Protein fractions [6]				
Rumen degradable intake, g	730	850	980	1110
Rumen degradable required, g	600	610	620	630
Rumen degradable balance, g	130	240	360	480
Metabolizable intake, g	812	820	841	855
Metabolizable required, g	746	750	756	765
Metabolizable balance, g	66	70	84	90

[1] Dry rolled corn
[2] Dried distillers grains with solubles (Big River Resources Boyceville LLC, Boyceville, WI)
[3] Dry ground wheatgrass straw mix
[4] Supplement formulated to contain 56.8% sugar and 7.4% RDP (Westway Feed Products, Tomball, TX).
[5] Supplement formulated to contain 270 mg monensisn/hd/d (Rumensin, Elanco Animal Health, Greenfield, IN).
[6] Protein fraction supply, requirement and balance determined from performance (Table 3) and feed ingredient composition (Table 1) using the NASEM (2016) Beef Cattle Nutrient Requirements Model.

Table 3. Growth performance and iterated metabolizable energy (ME) intake and ME content of test ingredient (sugar) in cattle fed a 1.16 Mcal NE_g/kg diet supplemented with sugar concentrations from 0% to 10.5%

	Sugar supplementation, % of dietary DM					Contrasts [a] *P*-value		
Item	0.0%	3.5%	7.0%	10.5%	SE	L	Q	C
Pens, *n*	8	7	8	7				
In BW, kg	320	322	330	326	12.9			
DMI, kg/d	8.89	8.98	9.18	9.28	0.25	0.14	0.95	0.59
ADG, kg	1.53	1.49	1.49	1.45	0.09	0.38	0.90	0.61
ADG adjusted to same DMI, kg [b]	1.53	1.48	1.47	1.41	0.10	0.26	0.95	0.59
Feed DM/kg gain, kg [b]	5.97	6.15	6.21	6.44				
Final BW, kg	439	436	438	435	6.8	0.55	0.96	0.47
ME, Mcal/kg	2.72	2.66	2.65	2.59	0.03	0.10	0.96	0.60
MEI, Mcal/d	24.20	23.97	24.35	24.11	0.4	0.91	0.99	0.42

[a] L = linear, Q = quadratic, C = cubic.
[b] Feed conversion ratio listed as a reference, however, feed efficiency was analyzed as the effect of treatment on ADG using DMI as a covariate

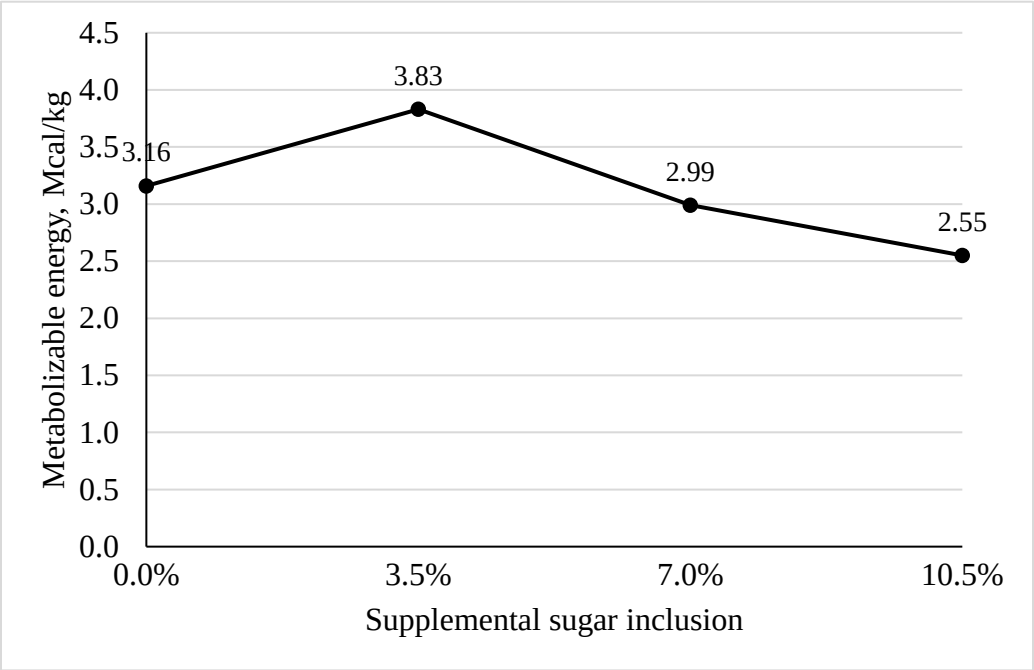

Figure 1. Least square means of ME concentration of dry rolled corn (at 0% supplemental sugar inclusion) or that of sugar supplement at incremental inclusions between 3.5% and 10.6% of diet DM. There was a quadratic response ($P = 0.03$) and a trend for a cubic response ($P = 0.09$) for ME of test ingredients when substituting starch for sugar. Metabolizable energy concentration of test ingredient was determined as follows: ME intake (derived from multiplying DMI by iterated dietary ME concentration) remaining after ascribing ME contributions of each non-test ingredient based on their respective intake and laboratory analysis was divided by intake of each test ingredient.

CHAPTER IV

MANAGING FEED DELIVERIES TO CORRECT FOR INGREDIENT DRY MATTER CHANGES DURING CATTLE FEEDING

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SYNOPSIS

Objectives of this study were to determine, based on performance, whether as-fed dietary composition adjustments are necessary as feed ingredient DM content changes and to validate on-farm feed ingredient dry matter determination methods. Seventy-six (load 1) crossbred steers (n = 57; 407 kg initial BW) and heifers (n = 19; 395 kg initial BW), and 75 (load 2) crossbred steers (n = 28; 402 kg initial BW) and heifers (n = 47; 374 kg initial BW) were allocated randomly (4 to 6 hd/pen) within sex, to one of two 15-pen rows in a deep-bedded confinement barn (each pen row contained one complete load). Treatments included a control (*n* = 15 pens), where as-fed diet composition was modified to account for changes in ingredient DM every 28 d (constant) or daily (adjusted; *n* = 15 pens). Target composition of diets was (DM basis) hay (3.73%), corn silage (CS; 8.28%), high moisture corn (HMC; 50.86%), dry distillers grains with solubles (DDGS; 11.83%), dry rolled corn DRC (20.07%), and a liquid supplement (5.23%). Cattle were fed for 84 d. Hay DM was determined daily using a microwave oven. Dry matter content of CS and HMC was determined every other day as each ingredient was removed from the bunker silo. Hay was the most variable ingredient (CV= 20.83%). Corn silage and HMC DM had a CV of 4.47% and 11.26%, respectively. Hay or CS DM measured on-farm was similar (P > 0.10) to that measured in the lab. Adjusting as-fed composition of the diet daily according to changes in DM content of hay, CS or HMC had no effect on DMI, ADG, feed conversion or BW (*P* > 0.05). Because as-fed deliveries were adjusted regularly to compensate for changes in DM content of hay, CS or HMC, residual suggested feed delivery variance was greater (*P* < 0.02) for pens receiving the as-fed diet composition adjusted daily. However, because

feed deliveries were managed based on visual observations of feed remaining in the bunk, residual DMI variance between treatments was comparable ($P > 0.05$). In this study, precipitation events or dietary concentration of ingredients with large moisture content fluctuations may not have been large to affect DM content of feed ingredients sufficiently to change DM content of the diet.

Keywords: Feedlot, intake variation, bunk management

INTRODUCTION

Managing day-to-day variation in dry matter intake (DMI) through the feeding period is critical in maximizing animal efficiency and performance. Subacute and acute ruminal acidosis, often caused by engorgement of starch, may result from variation in intake of cattle fed high-concentrate diets (Fulton et al., 1979; Owens et al., 1997). Although variation in intake may not always result in acute ruminal acidosis, it reduced feed conversion efficiency (Owens et al., 1997). In an effort to minimize fluctuations in DMI, bunk management was developed based on a numerical scoring system to prevent variations in DMI (Pritchard, 1993). However, due to the magnitude of human error that can occur prior to feed being delivered, care in batch mixing is necessary to ensure accurate loading, mixing and delivery (Pritchard and Bruns, 2003). Considerable research was conducted to understand how variation in feed delivery, frequency of delivery and delivery time affect animal performance (Galyean et al., 1992; Pritchard, 1993; Zinn, 1995; Cooper et al., 1997; Lawrence, 1998; Soto-Navarro et al., 2000; Pritchard and Bruns, 2003). Yet, to our knowledge there is no research evaluating how ingredient DM fluctuations affect dietary DM content, DMI or performance.

Large and unpredictable annual precipitation in the Midwestern United States may influence harvest schedule thus resulting in varying moisture concentration of stored feed. Precipitation in the form of snow or rain on stored feed piles, bags or open faces in bunker silos also leads to changes in moisture content of stored feed. Similarly, evaporation of moisture from bunker silo or bag faces or piles may reduce moisture in stored feeds during dry spells.

In dairy cattle, corn silage was the most variable feedstuff where variation in DM content ranged from 5.1 to 10.4 percentage units (Weiss et al., 2012). Objectives of this study were to determine, based on performance, whether as-fed dietary composition adjustments are necessary as feed ingredient DM content changes and to validate on-farm feed ingredient dry matter determination methods. We hypothesized that adjusting as-fed diet composition in response to changes in feed ingredient DM should maintain consistent DM delivery and intake resulting in improved performance as measured by gain and feed efficiency of cattle fed a high-energy diet for 84 d.

MATERIALS AND METHODS

All animal handling and procedures were approved by the Institute of Animal Care and Use Committee at the University of Minnesota. Steers and heifers utilized in this study were housed in facilities located at the University of Minnesota Beef Research and Education Unit in Rosemount, MN.

Animals and facilities

Seventy-six crossbred (load 1) steers (n = 57; 407 kg initial BW) and heifers (n = 19; 395 kg initial BW), and 75 crossbred (load 2) steers (n = 28; 402 kg initial BW) and heifers (n = 47; 374 kg initial BW) were allocated (4 to 6 hd/pen) within sex, to one of two 15-pen rows in a deep-bedded confinement barn (each pen row contained one complete load). Upon arrival, cattle had been fed a receiving diet supplemented with either a direct-fed microbial and prebiotic or a placebo (corn gluten feed) for 49 d. During the receiving phase, cattle received infectious bovine rhinotracheitis, parainfluenza$_3$, bovine respiratory syncytial virus intranasal vaccine (INFORCE 3 Zoetis, Inc. Parsippany, NJ), infectious bovine rhinotracheitis, bovine viral diarrhea, parainfluenza$_3$,

bovine respiratory syncytial virus modified live vaccine, *Mannheimia haemolytica – Pasteurella multocida* bacterin-toxoid (Titanium 5 + PH-M, Elanco Animal Health, Greenfield, IN), and an intramuscular *Clostridium (C.) chauvoeis, C. septicum, C. haemolyticum, C. novyi, C.sordellii, C.perfringens* Types C and D bacterin-toxoid (Ultrabac 8, Zoetis , Inc. Parsippany, NJ. Extended release trenbolone acetate and estradiol implants (200 mg trembolone acetate and 40 mg estradiol; Revalor – XS, Merck Animal Health, Madison, NJ) and (200 mg trembolone acetate and 20 mg estradiol; Revalor-XH, Merck Animal Health, Madison, NJ) were administered to steers and heifers, respectively 28 to 30 d after cattle arrived.

Pen rows were contained north or south of a 6.7 m feed alley; each row contained each block (load and sex). Pens measured 3 m wide by 9 m deep. A continuous bunk line (14" Deep Yard Bunk, Weiser Concrete, Maiden Rock, WI) was separated between each pen by a solid metal divider to prevent feed from being shared between pens; each pen had 3 m of bunk space allowing for 50 to75 cm of bunk space per head. Each pen contained a heated, automatic water tank (Omni 1, Ritchie Industries Inc., Conrad, IA). Pens were bedded as needed using corn stalks. Bedding was added when the bed pack was deemed to be excessively wet (seeping from bed pack) from precipitation or manure.

Cattle were weighed after withdrawing feed and water for 16 h to determine initial and final shrunk BW. Weights were also obtained before feeding every 28 d.

Dietary treatments

Pens, within block (side of barn and load) were assigned to one of two dietary treatments consisting of adjusting as-fed dietary composition at 28-d intervals (constant) or daily (adjusted). Adjustments to as-fed composition were made as consequence of

changes in DM content of hay, CS and HMC. The 28-d periodic adjustment served as the control, and was performed to represent current industry practice (Samuelson et al., 2016). Target diets were comprised (DM basis) of hay (3.73%), corn silage (CS; 8.28%), high-moisture corn (HMC; 50.86%), dry distillers grains with solubles (DDGS; 11.83%), dry rolled corn (DRC; 20.07%), and a liquid supplement (5.23%). Cattle were fed once daily at 0700 h. Feed ingredients were loaded in a vertical mixer (Patz 270, Patz Corp., Pound, WI) in the following order: hay, CS, HMC, DDGS, DRC, liquid supplement. One load was mixed for each treatment daily. Feed loading and diet deliveries to pens were recorded daily on a cloud-based program (Performance Beef, Performance Livestock Analytics, Ames, IA).

Ingredient storage

Ingredients were handled and stored according to current industry practices. The collection of practices employed resulted from verbal communication with nutritionists working with feedlot operators in the Midwest and our own observations. Round-hay bales, previously stored outside, were ground every 21 d and stored in a pile, on a bituminous surface within an empty bunker. Corn silage and HMC were harvested in September of the prior year and stored in bunkers silos (7.3 x 27.43 x 2.5 m), packed to achieve a density of 224 kg/m^3 and were covered with a plastic tarp and mesh netting (Secure Covers, Hansen Silos, Lake Lillian, MN) to maintain integrity of the tarp and feed. Plastic was removed so no more than 1.2 m were exposed at a time for. Dry rolled corn was stored in bins and loaded directly into the mixer via auger. Dry distillers grains with solubles was stored in a single bay within a covered feed shed. Liquid supplement

was stored in a bulk tank and pumped to mixer for loading. The feed mixer remained stationary during loading and mixing.

Hay was transported daily directly from the pile to the feed mixer daily as needed per load. Face on CS and HMC bunkers was raked vertically every other day using a silage rake to remove and hold the required amount of each ingredient to load the mixer for two consecutive days. This was accomplished to optimize equipment use while preventing feed ingredients from becoming stale. Both feed ingredients were then transported to individual bays in the covered feed shed to await mixer loading.

Ingredient sampling and DM determination

The hay pile was sampled and DM content determined using a microwave oven every morning prior to feed mixing. Corn silage and HMC were sampled and DM content was measured (via grab sample after feedstuffs were faced) on the days these ingredients were removed from bunker silos. Corn silage and HMC were delivered at the feed shed prior to sampling. Dry rolled corn and DDGS were sampled and measured for DM content weekly (via grab sample from bin and pile). Liquid supplement was collected every other week but was not dried on farm or used to adjust as-fed feed deliveries. For all ingredients, when samples were taken, they were divided in half: one half was used to determine on-farm DM and the other half was frozen at (-20 ^{o}C) until laboratory DM could be measured.

Hay (30 g) was dried using a microwave (MW8775W, Emerson Radio Corp, Parsippany, NJ) following the method outlined by Loy et al., (2016). Hay was dried in the microwave in 30-sec intervals to avoid starting a fire and weighed until dry weight was constant. Corn silage, HMC, DDGS and DRC were dried (100 g) using a commercial

forced-air drying instrument (Koster Moisture Tester Inc, Medina, Ohio) until dry weight remained constant. Resulting on-farm ingredient DM were updated, once monthly for constant or daily for adjusted, into a cloud-based cattle feeding program (Performance Beef, Performance Livestock Analytics, Ames, IA) that derived as-fed diet composition for each pen from individual daily DMI. Targeted daily DMI resulted from daily bunk calls (0, slick bunk to 4, 100% feed in bunk) wherein two consecutive days with bunk calls of 0 resulted in increased DM offering (0.22 kg/head). Bunk calls at or greater than a score of 1 elicited a reduction in DM offer equivalent to 2.5%, 5%, 10% or 20% of previous day offer, respectively, when bunk scores were 1, 2, 3, or 4. Feed refusals (orts) were weighted and sampled when, in the morning, feed remaining in the bunk appeared to be more than 0.45 kg DM and frozen at -20^{o} C until further analysis. Orts and ingredients were then transported to campus (University of Minnesota, Haecker Hall, St. Paul, MN) where they were dried at 60 ^{o}C for 48 h (Blue M, Thermal Product Solutions, New Columbia, PA) in a commercial drying oven to generate ingredient DM standards to validate on-farm DM methods.

Residual feed delivery and intake variance

Suggested daily feed delivery and intake (each expressed as DM) variance were calculated according to procedures outlined by Stock et al. (1995). Briefly, within-pen, each suggested feed delivery (kg diet as-is/head) and actual DMI (kg DM/head) was averaged across the 84-d feeding period. Each of these averages were subtracted from suggested daily feed delivery or actual DMI, respectively. This resulted in residual (deviations from the pen mean) delivery (RD) or residual DMI (RDMI). Variance of

each of these deviations was determined for each pen across the entire feeding period, and represents within-pen residual feed delivery or DMI variance, respectively.

Suggested as-fed delivery was chosen to represent variance generated by interventions required to modify ingredient loading resulting from adjustments to DM content of specific ingredients or those resulting from fluctuations in bunk calls (intake). Suggested as-fed delivery is not subject to errors in feed delivery that would be present in actual as-fed delivery. Variance of DMI simply represented the response to all factors involved in presenting feed at the bunk: response to bunk calls (previous intake), inadvertent changes in dietary DM content, and adjustments to as-fed dietary composition resulting from changes in ingredient DM content.

Statistical analysis

The study was analyzed as a completely randomized block design blocked by load (or pen row). Performance data and variance were analyzed using Procedure Mixed of SAS (SAS 9.4, Cary, NC). Pen was the experimental unit. Variables of interest were initial and final weights, ADG, DMI, and feed efficiency, and variances of RD and RDMI. The model to test effects of treatment and block on dependent variables contained terms for treatment (τ), block (β; random), sex and head:

$$Y_{ijk} = \mu + \tau_i + \beta_j + Sex_k + head + \varepsilon_{ijk}$$

Feed efficiency was analyzed as the response by ADG to treatment effects using DMI as a covariate in the model. This approach permits determination of effects of DMI (set by covariate analysis) on ADG. In the results, feed efficiency is expressed both as this

variable and as least square means (with no *P*-values) of feed required per unit of gain for ease of interpretation. A regression using Procedure Regression of SAS was performed using on farm DM and oven DM to validate on-farm DM determination. An F-test to test the null hypothesis that the intercept was 0 and slope was 1 was conducted (Mayer et al., 1994). Least square mean difference *P*-values were adjusted in the LSMEANS statement of SAS and statistical significance was declared when *P*-values were less than 0.05.

RESULTS AND DISCUSSION

The 84-d feeding period spanned the months of July, August and September. Rainfall data recorded for the period of study was compared to average data maintained by the University of Minnesota's Research and Outreach Center (Rosemount, MN; U.S climate data, 2019). Over the 84-d feeding period (Figure 1), July and August were drier than average, where total rainfall was 6.12 cm and 1.39 cm, respectively, (corresponding average rainfall for the months of July and August is 11.40 cm and 11.98, respectively). However, September had twice the rainfall than average (15.37 cm vs 9.19 cm) than normal.

Ingredient DM and method validation

Over the 84-d study, hay averaged 70% DM and was highly variable (CV = 20.83%). Hay was the only ingredient stored without cover, which explains the large variation in DM content (Table 1). Corn silage was described as the feed ingredient with the most variation in DM content (McBeth et al., 2013). In the current study, of the feed ingredients stored in a bunker silo or other storage structures, corn silage DM content was

also the most variable (CV= 11.26%). Coefficient of variation in DM content of HMC was 4.88%, which is in agreement with previous observations (Weiss et al., 2012). Dry matter content of DDGS, DRC and liquid supplement had CV of 1.51, 0.39, and 1.48%, respectively. This was expected as these ingredients were stored protected from the elements until loading and mixing.

Figure 2 represents three regression lines between DM content of hay, CS, and HMC measured using on-farm on DM content of these ingredients measured in the laboratory; a full agreement line corresponding to zero intercept and a slope of 1 is also included. Because the validation regression line for corn silage or hay had an intercept no different than zero and a slope no different than one (F-test $P > 0.10$), demonstrated that using a Koster moisture tester to determine DM content of corn silage or a microwave oven to determine the DM content of hay provided estimates of DM content of these ingredients that were not different than those yielded by drying them in a forced-air oven at 60 °C for 24 h. In contrast, the F-statistic for the hypothesis test of zero intercept and slope of one between on-farm and laboratory DM content of HMC resulted in $P < 0.05$. This result indicates that values of DM content obtained by drying HMC in a Koster tester were different than those obtained in the laboratory. These results contradict those reported by Oetzel et al. (1992) who concluded that using the Koster moisture tester consistently under-dried all ingredients.

The variation (expressed as either SD or CV) between both methods were comparable for all ingredients except DRC and DDGs, in which the variation for on-farm drying was greater than that determined in the laboratory (Table 1). This could be explained by the amount of fines in DDGS and DRC as compared with CS and HMC,

which either blew out from the forced-air oven or fell through the screen of the Koster tester during the drying process. Ultimately, dietary DM determined from on-farm-tested ingredients were numerically less than dietary DM calculated from laboratory DM (Table 2). Dietary DM content and its variation were similar between diets regardless of how often the as-fed composition was adjusted (Table 2).

Performance data

After 84 d-on-feed, DMI, ADG, feed efficiency and final BW were similar ($P >$ 0.33) regardless of how often as-fed dietary composition was adjusted in response to changes in feed ingredient DM (Table 3). Failure to observe performance differences based on how often as-fed dietary composition was adjusted to compensate for changes in DM content likely resulted from lack of inherent or weather-imposed (Figure 1) variation in DM content of stored feed ingredients (Table 2), and daily adjustments to feed on offer resulting from bunk management. Absence of inherent or environmental effects resulted in similar dietary DM content of both diets (Table 2).

Suggested feed delivery variation (Table 4) represents the response by the individual delivering feed to bunk score recorded for that day. A tendency ($P = 0.06$) for greater within-pen variation in feed delivery was recorded for the diet adjusted daily. This was expected as changes in DM content of any of the feed ingredients under constant surveillance led to changes in as-fed dietary composition. However, there was no difference ($P = 0.86$) in residual DMI variance resulting from adjusting as-fed dietary composition daily or every 28 d. This demonstrated that intake was similar regardless of how frequent as-fed dietary composition was adjusted.

Our results agree with those of Cooper et al. (1999) who reported no difference in gain or feed efficiency when cattle were fed ad-libitum with an imposed intake variation of 1.8 kg/d. In our study, cattle fed diets adjusted for as-fed composition daily or every 28 d had daily intake variation of 0.90 kg/d, respectively. However, in a previous study with cattle programmed to gain 1.25 kg/d, imposed daily intake fluctuations of 10% (as much as 1 kg/d) reduced ADG by 7% (Galyean et al., 1992; Soto-Navarro et al., 2000). These results suggest that in certain situations such as when intake is limited, cattle may be more prone to respond to fluctuations in intake. Cattle programed to gain a specific amount are only delivered enough feed to fulfill a specific gain, resulting in rapid intake of daily feed allotment and not allowing them to over eat (Pritchard, 2003) making them more prone to overeat when presented the opportunity. On the other hand, feeding cattle ad-libitum may cause daily intake variation due to self-induced intake fluctuations causing the rumen to adapt to these changes. Cooper et al. (1999) suggested that cattle exposed to intake variation adapted to this condition. Cooper et al. (1997) also speculated, when cattle are fed ad-libitum, fluctuations in DMI may serve as a buffer for days of over-consumption. However, Bierman and Pritchard (1996) demonstrated that if deliveries are not managed, ad-libitum feeding (resulted daily feed delivery variation similar to that in Cooper et al. 1999; Pritchard and Bruns. 2003) can affect feed efficiency.

In this experiment, DMI was determined as the difference between feed DM delivered and feed DM refused. If DMI thus measured represents the net effect of dietary, environmental, animal and human factors on appetite, and no other effects on performance were measured, it follows that the net effect of these factors was not

sufficient to affect DMI or that standard operating procedures (SOP) prevented any of these factors from exerting an exaggerated effect on DMI. In the present experiment lack of excessive precipitation and/or adherence to SOP such as preventing excessive exposure of stored corn silage and high-moisture corn to precipitation, diligent bunk scoring and responsive bunk management all contributed to no performance response resulting from changes in DM content of feed ingredient regardless of how often as-fed dietary composition was adjusted to compensate for these changes.

SUMMARY

Using a microwave and Koster moisture tester to determine DM content of hay and corn silage, respectively, resulted in determinations of DM that were similar to those obtained through laboratory procedures. However, estimates of DM content of high-moisture corn determined using the Koster tester were different than those obtained by laboratory procedures. Adjusting as-fed dietary composition resulting from changes in DM content of hay, corn silage or high-moisture corn daily resulted in no benefit over adjusting as-fed dietary composition every 28 d likely because effects of precipitation on stored feeds were small or effectively managed by SOP in place such as preventing excessive exposure of stored corn silage and high-moisture corn to precipitation, diligent bunk scoring and responsive bunk management.

Table 1. Average ingredient DM measured either daily or every other day over an 84 d feeding period

Item [3]	On-farm[1]			Laboratory[2]		
	DM, %	Standard deviation	CV, %	DM, %	Standard deviation	CV, %
Hay [4]	71.20	13.34	19.16	70.09	14.60	20.83
Corn silage	32.85	3.80	11.57	34.44	3.88	11.26
HMC [5]	60.39	2.95	4.88	64.39	2.88	4.47
DDGS [6]	84.76	2.48	2.92	90.52	1.37	1.51
DRC [7]	86.63	3.20	3.69	88.71	0.50	0.39
Liquid Supplement [8]	-	-	-	68.28	0.97	1.41

[1] On-farm DM of Hay was determined using a microwave oven (MW8775W, Emerson Radio Corp, Parsippany, NJ). Other ingredients were dried using a forced air conventional oven (Koster Moisture Tester Inc, Medina, Ohio)
[2] All ingredients were dried using a commercial drying oven (Blue M, Thermal Product Solutions, New Columbia, PA) at 60 ^{o}C for 48 h
[3] Ingredients were sampled, Hay daily, CS, HMC, DDGs and DRC every other day and Liquid supplement every other week. At times of sampling half of each sample was dried and rest was dried at -20 ^{o}C until laboratory drying.
[4] Dry ground wheat straw grass mix
[5] High moisture ground corn
[6] Dried distillers grains with solubles (Big River Resources Boyceville LLC, Boyceville, WI)
[7] Dry rolled corn
[8] Not tested for on farm DM content. Supplement formulated to contain 320 mg monensisn/kg (Rumensin, Elanco Animal Health, Greenfield, IN).

Table 2. Dietary ingredient composition of diets (DM) fed to constant or adjusted treatments and based on on-farm or laboratory DM measurements

Item	Target	On-farm DM		Laboratory DM	
		Constant	Adjusted	Constant	Adjusted
Dietary Ingredient	----------DM basis----------				
Hay [1]	3.73	3.54	3.79	3.49	3.49
Corn silage	8.28	8.23	8.32	8.22	8.22
High moisture corn	50.86	51.2	50.65	52.00	52.00
DDGS [2]	11.83	11.82	11.85	12.02	12.07
DRC [3]	20.07	20.05	20.20	19.56	19.69
Liquid supplement [4]	5.23	5.17	5.20	4.87	4.90
DM, % [5]	65.81	62.72	62.69	65.86	65.70
Standard deviation	2.94	2.37	2.85	2.39	2.73
CV, %	4.48	3.78	4.55	3.63	4.15
NE_m, Mcal/kg	2.13	2.13	2.13	2.14	2.14
NE_g, Mcal/kg	1.43	1.43	1.43	1.44	1.44

[1] Dry ground wheat straw grass mix
[2] Dried distillers grains with Solubles (Big River Resources Boyceville LLC, Boyceville, WI)
[3] Dry rolled corn
[4] Supplement formulated to contain 320 mg monensisn/ kg (Rumensin, Elanco Animal Health, Greenfield, IN).
[5]Target diet DM represents the resulting dietary ingredient and nutrient content based on suggested ingredient load weights and laboratory DM content of each ingredient.

Table 3. Growth performance calculated using both on-farm DM and laboratory DM measures by cattle fed a 1.40 Mcal NE_g/kg diet either allowed to fluctuate with changing ingredient DM (Constant) or adjusted to represent fluctuations in ingredient DM content (Adjusted)

Item	On-farm[1]				Laboratory[2]			
	Constant	Adjusted	SE	*P* value	Constant	Adjusted	SE	*P* value
Pens, *n*	15	15			15	15		
Initial BW, kg [3]	392	395	28.91	0.71	392	395	28.91	0.71
DMI, kg/d	8.61	8.77	0.89	0.33	9.02	9.18	0.93	0.36
ADG, kg	1.77	1.78	0.29	0.79	1.77	1.78	0.29	0.79
ADG adjusted to same DMI, kg [4]	1.77	1.76	0.13	0.58	1.77	1.76	0.13	0.58
Feed DM/kg gain [4]	4.93	4.89	0.15		5.13	5.17	0.16	
Final BW, kg [3]	538	542	51.88	0.72	538	542	51.88	0.72

[1] Performance data analyzed using intake data generated from on-farm determined DM
[2] Performance data analyzed using intake data generated from laboratory determined DM (48 h at 60 ^{o}C in a commercial drying oven)
[3] After withholding feed and water for 16 h.
[4] Feed conversion ratio listed as a reference, however, feed efficiency was analyzed as the effect of treatment on ADG using DMI as a covariate

Table 4. Variance [1] of daily suggested feed delivery and DMI within pen for cattle fed diets either adjusted on an as-fed basis for changes in ingredient DM or held constant

Item, kg^2	Laboratory		SE	*P* – value
	Constant	Adjusted		
Within pen suggested feed delivery, kg^2 hd	0.58	0.67	0.033	0.06
Within pen DMI kg^2 hd	0.79	0.80	0.037	0.86

[1] Variances calculated using suggested deliveries and DMI based on oven ingredient DM

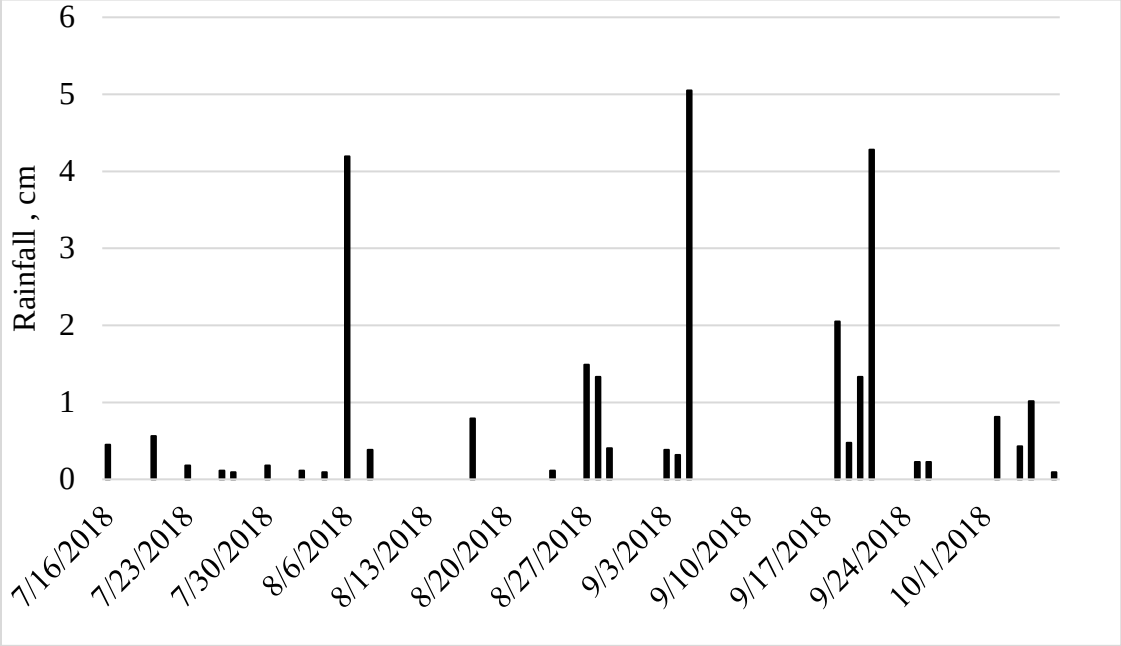

Figure 1. Daily precipitation (rainfall, cm) over the 84-d feeding period (Rosemount, MN; U.S climate data, 2019). July and August were drier on average, where total rainfall were 6.12 cm and 1.39 cm respectively (11.40 cm and 11.98 average normal rain fall for July and August, respectively). September had twice the rainfall on average (15.37 cm measured vs 9.19 cm average; Rosemount, MN; U.S climate data, 2019).

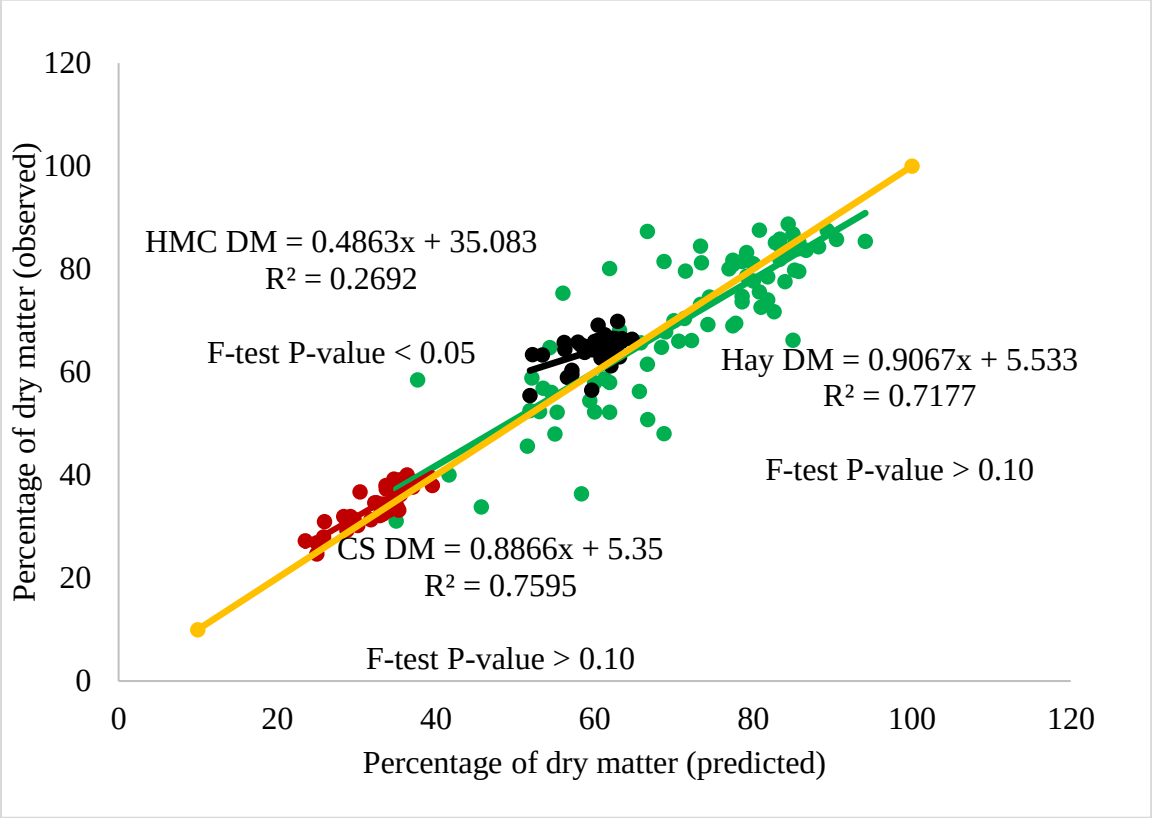

Figure 2. Validation of on-farm dry matter determining methods, microwave (hay, • ,) and Koster moisture tester (corn silage, CS, • , and high-moisture corn, HMC, •), against laboratory method (drying in 70 °C forced air oven for 48 h). Using a microwave (hay) or a Koster Moister Tester (CS and HMC) to determine DM.

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