THE EFFECTS OF DIETARY ADAPTATION PROGRAMS ON FEEDLOT CATTLE PERFORMANCE AND EVALUATION OF RUMINAL MONITORING DEVICES IN AN ACIDOSIS CHALLENGE

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CHAPTER I

INTRODUCTION

In the cattle feeding industry, high input costs of feed, labor, and overhead make improvements in cattle performance essential for economic success. Within the past year, cattle prices have increased, however feed costs are also higher. According to Hendersen (2011) feed costs currently account for more than 28% of the total feeding costs, which are up from 19% in 2010. Due to the need for increased feedlot efficiency, efforts have been made to reduce costs by utilizing various by-product feed sources as a substitute for more traditional concentrate sources. Although dry rolled corn (DRC) has been traditionally used, by-products from ethanol production have provided alternate sources of protein and energy in feedlot finishing diets. Results of research indicate increased beef cattle performance when distillers grains are included in feedlot diets with traditional feed sources such as DRC (Larson et al., 1993; Ham et al., 1994; Al-Suwaiegh et al., 2002), high moisture corn (HMC) and steam flaked corn (SFC) (Corrigan, 2007) as compared to those traditional feed sources fed alone.

Digestive disorders are blamed for a majority of decreased performance within the cattle feeding industry. Galyean and Rivera (2002) reported that 25 to 33% of deaths of feedlot cattle can be contributed to digestive disorders. Specifically, acidosis, a common metabolic disorder, is the result of acid accumulation in the rumen due to overconsumption of a highly fermentable carbohydrate. Within a large pen feedlot setting, acidosis is commonly present in cattle at a subacute or chronic level. Subacute or chronic acidosis leads to variable intake causing reduced

performance during the feeding period all contributing to losses of $15 to $20 per animal(Schwartzkopf-Genswein et al., 2003). Contributing factors to the incidence of acidosis include, grain type, grain processing, adaptation procedures, and animal variation.

In the past, severity of ruminal acidosis has been predominantly measured by the level of ruminal pH. More recently, research has been conducted to evaluate ruminal temperature as an indicator of metabolic activity in the rumen using various levels of dietary concentrate (AlZahal et al., 2008; AlZahal et al., 2009). In an effort to further understand the etiology of acidosis, ruminal monitoring devices have been used monitor ruminal pH and temperature levels when using combinations of various feed components. These devices have provided insight into relationships between ruminal factors and metabolic disorders (Cooper, 1998; Schwartzkopf-Genswein et al., 2004).

Methods and time spent adapting cattle to feedlot finishing diets are a critical aspect in which nutritional management practices can potentially promote or impair subsequent performance and health (Brown et al., 2006). Adaptation involves incremental changes from a roughage based diet to one based primarily on concentrate. During adaptation, the rumen microbial population is provided gradual increases in concentrate to adapt the rumen microbes to a greater number of amylolytic and reduced amount of fibrolytic bacteria (Goad et al., 1998). Due to the high level variation of animals within each pen, Bevans et al. (2005) suggests tailoring adaptation programs to the most susceptible animal in each pen. Traditionally, adaptation was accomplished using transition diets providing cattle with increasing grain and decreasing amounts of roughage or a period of 21 to 28 d (Krehbiel, 2006). A gradual adaptation to the finishing diet is encouraged to reduce metabolic disorders often experience by cattle subjected to rapid grain adaptation.

Feedlot adaptation programs vary from one operation to the next. A survey conducted by Vasconcelos and Galyean (2007) found that 75% nutritionists within the survey utilized 'step-up' methods to adapt cattle to a finishing diet. This particular method requires three to five transition diets being fed three to seven days each during the adaptation period. Within two-ration blending, cattle receive daily incremental decreases of a starter diet and increases of a finisher diet over a period of 21 to 28 d. The two-ration blending adaptation method reported less frequent use (14%) (Vasconcelos and Galyean, 2007), however, should reduce the complexity of and number of loads required in the feed yard per day, however, more intensive management is required to monitor feeding two different rations in one day (Krehbiel, 2006; Burken, 2010). This adaptation method also assumes that all cattle in a pen consume equal proportions of each ration daily, but this assumption may not be correct (Krehbiel, 2006).

LITERATURE CITED

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002. Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim Sci. 80: 1105-1111.

AlZahal, O., E. Kebreab, J. France, M. Froetschel, and B. W. McBride. 2008. Ruminal Temperature May Aid in the Detection of Subacute Ruminal Acidosis. J. Dairy Sci. 91: 202-207.

AlZahal, O., M. A. Steele, E. V. Valdes, and B. W. McBride. 2009. Technical note: The use of a telemetric system to continuously monitor ruminal temperature and to predict ruminal pH in cattle. J. Dairy Sci. 92: 5697-5701.

Brown, M. S., C. H. Ponce, and R. Pulikanti. 2006. Adaptation of beef cattle to high-concentrate diets: Performance and ruminal metabolism. J. Anim Sci. 84: E25-E33.

Burken, D. 2010. Evaluation of diet adaptation programs and supranutritional dietary antioxidants for feedlot cattle. M.S., Oklahoma State University.

Cooper, R., T. Kopfenstein, R. Stock and C. Parrott. 1998. Observations on acidosis through continual feed intake and ruminal pH monitoring. .

Corrigan, M. E., G. E. Erickson, T. J. Klopfenstein, K. J. Vander Pol, M. A. Greenquist, and M. K. Luebbe. 2007. Effect of Corn Processing and Wet Distillers Grains Inclusion Level in Finishing Diets, University of Nebraska, Lincoln, NE.

Galyean, M. L., and J. D. Rivera. 2003. Nutritionally related disorders affecting feedlot cattle. Can. J. Anim. Sci. 83: 13-20.

Goad, D. W., C. L. Goad, and T. G. Nagaraja. 1998. Ruminal microbial and fermentative changes associated with experimentally induced subacute acidosis in steers. J. Anim Sci. 76: 234-241.

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grains with solubles as a source of protein and energy for ruminants. J. Anim Sci. 72: 3246-3257.

Hendersen, G. 2011. Profit tracker: prices up, profits down. Drovers/Cattle Network. Accessed 11/29/2011

Krehbiel, C. R., B. P. Holland, and C. T. Milton. 2006. Grain processing effects on management: adaptation diets. In: Proc. of the Oklahoma State University Cattle Grain Processing Symp., Tulsa, Oklahoma. p pp. 156-166.

Larson, E. M., R. A. Stock, T. J. Klopfenstein, M. H. Sindt, and R. P. Huffman. 1993. Feeding value of wet distillers byproducts for finishing ruminants. J. Anim Sci. 71: 2228-2236.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, D. J. Gibb, D. H. Crews, Jr., D. D. Hickman, M. Streeter, and T. A. McAllister. 2003. Effect of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review. J. Anim Sci. 81: E149-158.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, T. A. McAllister, D. J. Gibb, M. Streeter, and A. D. Kennedy. 2004. Effect of feed delivery fluctuations and feeding time on ruminal acidosis, growth performance, and feeding behavior of feedlot cattle. J. Anim Sci. 82: 3357-3365.

Vasconcelos, J. T., and M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim Sci. 85: 2772-278

CHAPTER II

REVIEW OF LITERATURE

ACIDOSIS IMPACT ON THE FEEDING INDUSTRY

Due to the desire for increased growth and efficiency, feedlot cattle are fed to gain faster by consuming finishing diets of 85 to 95% concentrate. This practice has led to an increased need to manage against metabolic disorders The metabolic disorder most predominant in the industry is ruminal acidosis, a condition associated with overconsumption of rapidly fermentable carbohydrates (Owens et al., 1998). An acidosis event can occur during grain adaption due to poor adaptation techniques or when cattle are adjusting from a roughage diet to a diet higher in concentrate (Owens et al., 1998). At the end of the feeding period, there may be greater incidence of acidosis due to cattle being fed a high concentrate level for an extended period of time. Inefficiencies in bunk management, adaptation procedures, weather, grain type, and individual animal variability predispose cattle to acidosis (Cooper et al., 1999; Schwartzkopf-Genswein et al., 2003) . Other ailments associated with acidosis include laminitis, polioencephalomalacia, rumenitis, and liver abscesses. Decreases in efficiency of $15 to $20 per animal is due to variable feed intake caused by acidosis (Schwartzkopf-Genswein et al., 2003)

Subacute and acute acidosis

Chronic or subacute acidosis has been defined as ruminal pH of 5.2 to 5.6 where acute acidosis occurs at ruminal pH level below 5.2(Cooper, 1998). Although not as clinically severe, subacute acidosis is more detrimental to cattle feeding due to low and variable intakes leading to reduced ADG and poor efficiency (Owens et al., 1998; Cooper et al., 1999). Although apparent in individual feeding trials, it is very difficult to recognize the effects of subacute acidosis in a pen of feedlot cattle and these effects are often not recognized until the end of the feeding period.

Animal variation

Consistent bunk management practices such as timely feeding and complete mixing of diets are a good step in controlling acidosis in feedlot cattle. However, animal to animal variation results in challenges in the management of acidosis. An animal's variable response to low ruminal pH has been identified in various research trials where eating behaviors control the severity of an acidosis event (Hinders and Owen, 1965; Cooper, 1998; Brown et al., 2000). In the cattle feeding industry, cattle are commonly housed in large pens of more than 100 head. In situations such as these, social hierarchy will cause modifications to feeding behavior (Schwartzkopf-Genswein et al., 2003).

ACIDOSIS EFFECTS ON FERMENTATION AND DIGESTION

VFA absorption

Volatile fatty acids (VFA) are the primary energy source from ruminants, providing 55 to 80% metabolizable energy (ME) for the animal (Bergman, 1990; Sutton et al., 2003). The greatest concentration of VFA is found in the rumen with one fifth of the concentration present in the small intestine (Bergman, 1990). Acetate, propionate, and butyrate, primary VFA in the rumen, are produced mainly from fermentation of cellulose, fiber, starch, and sugar. Under normal conditions, acidity of the rumen is neutral requiring VFA to be present in a dissociated state. In sufficient concentrations, ruminal VFA stimulates blood flow within the ruminal

epithelium allowing normal keratinization to take place (Beharka et al., 1998). Large amounts of VFA are metabolized by the rumen epithelium during absorption processes and transport to the bloodstream (Bergman, 1990). However, when rapidly fermentable carbohydrates are ingested, ruminal pH is decreased and VFA absorption is enhanced due to increased permeability of the ruminal epithelium. Increased permeability on the ruminal epithelium allows un-dissociated acids to diffuse more readily. In a situation of overconsumption, glucose production is increased causing overproduction of VFA (Owens et al., 1998). When the rate of VFA production surpasses absorption, VFA accumulates, contributing to a continued reduction in ruminal pH (Owens et al., 1998). Accumulation of VFA causes abnormal growth and development of the ruminal epithelium which can lead to a condition called parakeratosis. Parakeratosis causes the stratnum corneum and stratnum granulosum layers of the rumen epithelium to thicken, (Hinders and Owen, 1965) potentially allowing ingested foreign particles to embed between the papillae permitting bacterial entry into the portal circulation.

Damage of ruminal epithelium results in a substantial decrease in VFA absorption. Krehbiel et al. (1995) illustrated that VFA absorption was significantly impaired in lambs enrolled in an acidosis challenge model. In that same study, liquid passage and absorption rates were showed to be impaired six months following the challenge accounting for a reduction of ME to the animal at 23 to 32%. Ruminal VFA absorption was reduced in a study by Hinders and Owens (1965) where cattle consuming dehydrated alfalfa pellets experienced a reduction of VFA absorption to levels of 30 to 63% as compared to those steers fed alfalfa hay.

Lactic acid

Under normal conditions, lactate is produced at levels below 5 μM from pyruvate to restore NAD for use in glycolysis, but when large amounts of glucose are introduced in the rumen from grain engorgement, lactic acid levels can exceed concentrations above 40 μM *(Owens et al., 1998).* Lactate is produced in D (+) and L form within anaerobic rumen environment.

Metabolized naturally in body tissues, L lactate is less of a factor in the severity of acidosis. In contrast, D (+) lactate cannot be utilized by the body and therefore can accumulate after grain engorgement. In a challenge study performed by Krehbiel et al. (1995), increased inter-ruminal dosage of glucose caused a significant increase in the concentration of plasma D (+)lactate.

Following overconsumption of rapidly fermentable carbohydrates, the amount of time until acidosis occurs depends on the animal's ability to withstand a ruminal acid load, the type of grain consumed and the extent to which it is processed. Incidence of overconsumption causes increased fermentation rate, making a large amount of glucose available to ruminal microbes. Free glucose within the rumen allows lactic acid producing bacteria such as *Streptococcus bovis* and Lactobacilli to flourish. As lactic acid accumulates, acid intolerant lactate utilizing bacteria are replaced by acid tolerant bacteria (Owens, 1993). Severity of acidosis will intensify as ruminal pH is driven down by the accumulation of acids, allowing continued proliferation of Lactobacilli. Overall, lactate levels in the rumen are commonly blamed as the cause of acidosis. However, Britton and Stock (1987) suggest that levels of pH can be reduced entirely by the accumulation of VFA in the rumen indicating that the accumulation of both lactate and VFA are responsible for ruminal acidosis.

Bicarbonate and blood pH

Bicarbonate concentration in blood and body fluids is crucial in maintaining body fluid pH (Carter and Grovum, 1990). . Specifically in the rumen, bicarbonate from saliva production is a significant source of buffer against ruminal acids. During consumption of high roughage diets, mastication occurs to a greater extent in turn increasing saliva production. Mastication is decreased during consumption of concentrate diets providing fewer buffers for the rumen. Within the rumen, bicarbonate enters from the blood in exchange for VFA during absorption (Owens et al., 1998) Because of increased ruminal acidity in high concentrate diets, a greater amount of bicarbonate is exchanged from the portal blood, reducing base excess and increasing

lactate concentration resulting in reduced blood pH (Krehbiel et al., 1995a; Owens et al., 1998; Brown et al., 2000).

Osmolality

Osmotic pressure regulates water through membranes around the rumen depending on concentrations of solutes within ruminal fluid (Owens et al., 1998). Normal rumen osmolality occurs at a range of 240 to 340 *m* on a roughage diet and will increase to 350 to 450 *m* on a high concentrate diet (Carter and Grovum, 1990; Owens, 1993; Owens et al., 1998). During acidosis, osmotic pressure of the rumen intensifies due to increased concentrations of minerals, D (+) and L lactate, glucose, and VFA (Carter and Grovum, 1990). Because of the increased osmolality within the rumen, water is directed into the rumen in an effort to equilibrate the pressure. In this instance, there is potential for abscesses to occur when portions of the ruminal epithelial membrane are damaged due to the entry of water (Ahrens, 1967; Eadie, 1970)

EFFECT OF DIET COMPOSTITION ON INCIDENCE AND SEVERISTY OF ACIDOSIS

Roughage level and type

The addition of roughage in ruminant diets increases mastication and rumination, which will positively affect the health of the rumen environment by adding buffer in the form of saliva. Roughage is an essential component of receiving and adaption diets. Efficiency can be improved in finishing diets when roughage inclusion is minimized. Different combinations of roughage and grain types will produce various results in cattle performance. Quinn et al. (2011) , fed cattle fed a distillers grains based diet various roughage sources and found that distillers grains fed in combination with alfalfa hay had decreased final BW, ADG, and HCW compared to those consuming distillers grains with burmuda grass hay or sorghum silage. An additional study demonstrated similar results in steers fed a diet containing wet corn gluten feed (WCGS). Average daily gains were increased in steers fed increasing inclusion levels of roughage however,

feed efficiency was decreased (Parsons et al., 2007). Similarly, Stock et al. (1990) demonstrated that feed efficiency was significantly decreased as roughage was added in diets containing dry rolled corn and dry rolled sorghum. In that same study, feed efficiency was not affected by roughage inclusion in diets containing dry rolled wheat. Bartle and Preston (1992) found that a reduction in roughage inclusion halfway through the finishing period did not have negative effects on steer performance or health and helped to reduce feed costs during that portion of the feeding period. This research shows variable results according to grain and roughage source, however, a roughage level of 5 to 15% is commonly fed during the finishing period to maximize cattle performance while maintaining ruminal pH above levels causing metabolic disorders (Crawford et al., 2008).

Grain level and type

When a high concentrate diet is consumed, microbial fermentation takes place, converting starch to glucose. This process is affected by the availability of starch within the grain. Factors that affect the availability of starch include processing method, grain source, and starch type. When grains are processed, the protein matrix surrounding the endosperm is disrupted and more surface area is made available for microbial digestion, increasing fermentation rates. Steam flaked (SFC) and high moisture corn (HMC) are forms of processed corn commonly utilized as a concentrate source due to high digestibility rates (Brown et al., 2000). Fermentation rates vary among grain sources, wheat and barley being most fermentable followed by corn and sorghum, respectively (Stock et al., 1990). A high extent of fermentation is preferred because of increased energetic efficiency but the incidence of acidosis increases when these feedstuffs are used. Conversely, a slower fermentation rate decreases the chance for acidosis but is less energy efficient (Owens et al., 1998).

Ionophores

It has become customary to utilize ionophores in feedlot diets to improve efficiency and increase gains. Efficiency is improved by maximizing the production of propionate in the rumen in relationship to acetate and butyrate. Propionate is produced by ionophore resistant gram (-) bacteria which will increase in concentration with decreased growth of gram (+) bacteria (Yokoyama, 1993). Metabolic disorders are also decreased in cattle when ionophores are included in high concentrate diets (Nagaraja et al., 1981; Owens et al., 1998). Grams (+) bacteria such as *Streptococcus bovis* and Lactobacilli are targeted by ionophores, decreasing their production of acetate, lactate, formate, and methane. Decreased production of these components allows the incidence and severity of metabolic disorders to be decreased (Burrin and Britton, 1986).

Ionophores such as monensin and lasalocid alter the normal ion transport within cells of gram (+) bacteria (Bergen and Bates, 1984; Yokoyama, 1993). Once ionophores enter the cell, internal pH will be lowered due to increased concentrations of H+. To maintain ruminal pH within the cell, H+ is pumped out by the ATPase enzyme system. The cell will continue this process, utilizing all energy to maintain internal pH rather than reproduce additional gram (+) bacteria. Gram (+) bacteria do not proliferate in the presence of ionophores, allowing increased growth of gram (-) bacteria. The effectiveness of monensin and lasalocid are illustrated in research studies where feed efficiency is improved and gains are increased with their inclusion in high concentrate diets (Nagaraja et al., 1981; Stock et al., 1990; Erickson et al., 2003). Monensin has also shown the ability to moderate feed intake in high concentrate diets, resulting in a decrease in the incidence of metabolic disorders (Erickson et al., 2003; Lunn et al., 2005). Tylosin, often incorporated with monensin, is an antibiotic used to prevent liver abscesses. When included in high concentrate diets, tylosin is effective in decreasing the prevalence of liver abscesses (Depenbusch et al., 2008) in addition to improving average daily gain and feed efficiency (Brown et al., 1975). Laidlomycin propionate is an additional ionophore used to

improve feedlot performance (Spires et al., 1990). Similar to monensin, Laidlomycin propionate has been shown to reduce intake variation, in turn decreasing the incidence of subacute acidosis during adaptation to a high concentrate finishing diet (Bauer et al., 1995).

Fat

The addition of fat at 1 to 2% inclusion into finishing diets can increase energy intake as well as provide useful characteristics when processed feeds are included in the diet (Byers, 1993; Ludden et al., 1995). There have been variable results in the effect of added fat on cattle performance (Zinn, 1989; Huffman et al., 1992). Gramlich et al. (1990) demonstrated a significant increase in feed efficiency when 4% tallow was added to a DRC based diet. However, additions of up to 6% fat in challenge diets showed a significant reduction in pH level and DMI compared to the addition of no fat (Krehbiel et al., 1995b). Additionally, Huffman et al (1992) showed increasing levels of bleached tallow will cause a significant decrease in DMI, ADG, and feed efficiency.

THE IMPORTANCE OF RUMINAL MONITORING SYSTEMS

Ruminal monitoring devices have become an option to detect illness, monitor vital signs, and predict parturition and estrus in cattle (Cooper-Prado et al., 2011). These devices have also been used as a method to determine relationships between ruminal factors and metabolic disorders such as acidosis (Cooper, 1998; Schwartzkopf-Genswein et al., 2004). In the past, measurement of acidosis by ruminal fluid sampling was the employed method of explaining variation of ruminal acid load. Although helpful in identifying primary complications of acidosis, fluid measurement alone leaves out variance that occurs between time point measurements. Monitoring of ruminal pH allows continuous collection of information during a measurement period, something not accomplished by manual fluid measurement alone (Cooper, 1998). As previously mentioned, acidosis affects each animal in a different way. Through utilization of technology, scientists might be able to more accurately identify the specific factors that affect

individual animals. In addition, a correlation of ruminal pH with ruminal temperature in the acidosis model has been formed using this technology

Acidosis effect on ruminal temperature

The level of ME intake is a determinant for the level of metabolic heat load experienced by the ruminant. Concentrate diets contain a greater amount of ME, issuing a greater metabolic heat load than diets higher in roughage (Mader et al., 2002). Finishing diets containing high levels of concentrate, rumination and fermentation processes contribute to metabolic heat load. The effect of heat load is shown in a study by Mader et al. (1999) where steers fed a 28% roughage diet ad libitum had significantly lower respiratory rates and body temperatures compared to steers on a 6% roughage diet ad libitum (Mader et al., 1999). Research such as this would support the relationship of high ruminal temperatures during an acidosis situation where a large amount of rapidly fermentable carbohydrates have been consumed.

In the past, severity of ruminal acidosis has been predominantly measured by the level of ruminal pH. More recently, research has been conducted to evaluate ruminal temperature as an indicator of metabolic activity in the rumen using various levels of dietary concentrate (AlZahal et al., 2008; AlZahal et al., 2009). Temperature range of 39° to 41° C corresponded to the ruminal pH range of 5 to 5.6 during subacute acidosis and correlation (R^2=0.77) of ruminal temperature was evident in subacute acidosis (ruminal pH < pH 5.6) induced cows that had high average ruminal temperatures in the range of 39° to 39.2° C (AlZahal et al., 2008).

DISTILLERS BYPRODUCTS

Use of ethanol byproduct in the feeding industry

From the years 2000 through 2008, corn production increased by approximately 13 million acres (Center, 2011). During that same time period, bushels of corn allotted for ethanol production increased from 628 million to 4.5 billion bushels (Service, 2010). Expansion of the ethanol industry and level of production has led to a large supply of distillers grains byproducts.

In forecast of future production rates, the Center for Agricultural and Rural Development stated that 40 to 88 million metric tons of distiller's grains could be produced per year by 2011. Tokgoz et al. (2007) predicted an increase in distiller's grains production in amounts greater than 88 million metric tons by 2016.

By-products fed to cattle come primarily from two separate processes; wet milling and dry milling. The dry milling process produces distillers grains, distillers solubles and distillers grains + distillers solubles, and each are available in the wet and dry form (Stock, 1999). During the fermentation process, all starch is removed from the grain leaving only one-third of the original DM, concentrating distillers by-products approximately three-fold (Klopfenstein et al., 2008). Wet milling encompasses the production of a variety of food products primarily used for human consumption (Stock, 1999). Corn gluten meal and corn gluten feed are the wet milling by-products most commonly utilized in the cattle feeding industry.

Initially, large supplies of by-products provided an additional feedstuff for the cattle feeding industry and due to ongoing research conducted by many universities and institutions, this feed source has become increasingly valuable, making up a large percentage of feedlot diets. At approximately 30% crude protein, distillers grains are an excellent protein source in feedlot finishing diets (Fanning, 1999; Klopfenstein et al., 2008). In addition, energy density, due to high lipid content (10 to 12%) of this feed source, has allowed it to be recognized as an energy source for stocker cattle, developing heifers, and cows (Erickson; Firkins et al., 1985; Fanning, 1999).

Energy value of WDGS

Larson et al. (1993) who conducted two yearling and calf finishing trials, found wet distillers by-products fed at 40 percent inclusion provided 47 and 29 percent more NE_g, respectively, than DRC. Ham et al. (1994) found similar results when feeding either wet distiller's grains + solubles (WDGS) or composites of dried distillers grains + solubles (DDGS)

fed at the 40% inclusion level replacing DRC. In this study, gains and feed efficiencies were significantly improved for cattle fed the distillers byproducts compared to cattle fed DRC. More recent findings have shown 20 and 40 percent WDGS inclusion provided 2.5 and 6.8 percent more NE_g than diets containing only HMC and DRC (Vander Pol, 2004).

Energy value of DDGS

Research has shown that dried by-product feeds such as DDGS vary in nutrient composition due to the differences in drying procedures by facility. Vander Pol et al. (2004) reported NE_g values of DDGS at 97.3 and 107.4 % at 20 and 40 % inclusion compared to the same amount of HMC. Provided as an energy supplement to heifers fed low and high quality forage, DDGS significantly improved ADG compared to a traditional corn source indicating the value of DDGS as both a protein and energy source (Loy, 2003; Morris, 2005).

Energy value of sorghum distillers grains

Dry milling plants have the ability to utilize a variety of grains ranging in quality. Research has shown influences of grain type on the nutrient value of distillers grains (Lodge, 1996). According to the Beef Cattle NRC (2000), DDGS and WDGS contain 29.5 and 29.7 percent crude protein (DM basis) and 10.3 and 9.9 percent fat (DM basis), respectively. A study conducted by Fanning et al. (1999) determined the energy value of corn and sorghum WDG. Fanning et al. (1999) concluded that NE_g values of corn and sorghum WDG were similar based on performance having a 34 percent greater NE_g value than DRC. Lodge et al. (1997) reported comparative NE_g values of sorghum wet distillers grains (SWDG), sorghum wet distillers grains + solubles (SWDGS), and sorghum dried distillers grains + solubles (SDDGS) with corn as 96, 102, and 80%, respectively.

Byproducts as DIP and UIP sources in diet

Proper ratios and concentration of degradable intake protein (DIP) and undegradable intake protein (UIP) are necessary for maximizing performance of ruminants. Soybean meal (SBM) is a

commonly used protein source valued for DIP and UIP content. Increased availability of by-product feeds has allowed distillers grains to become a substitute protein source for SBM. Furthermore, research results show evidence that DIP supplementation is not necessary in diets containing distillers grains as an energy or protein source due to the amount of urea recycling that occurs in the rumen (Waller et al., 1980; Stalker, 2004; Vander Pol, 2005). Relative crude protein values of SBM and corn dried distillers grains are 51.8 and 30.4 percent with UIP values at 34 and 52 percent, respectively (NRC, 2000). Research demonstrates protein values of sorghum distillers dried grains (DDG), sorghum DDGS, corn DDG, and corn DDGS to be 150, 130, 200, and 180 percent that of SBM, respectively (Waller et al., 1980). These values indicate the value of distillers grains as an alternative protein source, successfully providing DIP and UIP sources (Ham et al., 1994)

Sulfur

Sulfuric acid is used to control pH during fermentation and for cleaning procedures in ethanol production. This production procedure in turn adds sulfur to by-product feeds produced from the ethanol process. Microorganisms in the rumen produce hydrogen sulfide (H_2S) from sulfur (S), increasing the incidence of polioencephalomalacia (PEM) in cattle fed finishing diets containing large amounts of by-product feeds (Vanness, 2009). Nutritional guidelines recommend sulfur levels at 0.15 % for beef cattle (NRC, 2000) with maximum tolerance concentration at 0.40 % (NRC, 1980).

Research conducted by Vanness et al. (2009) and Sarturi et al. (2011) showed that feed efficiency was optimized at WDGS inclusion of 20 to 30%, regardless of sulfur content. However, inclusion levels above 40% decreased DMI, ADG, HCW, and fat thickness, regardless of the product being wet or dry. Additional research documented that 20% by-product inclusion or 0.46% sulfur content of diet is a baseline level for incidence of PEM (Vanness, 2009). Feedlot

trials have shown that roughage inclusion in the diet is necessary to manage dietary sulfur levels in diets containing by-product feeds (Vanness, 2009; Wilken, 2009). Although research indicates by-product inclusion at high levels increases the incidence for PEM, studies conducted utilizing by-products in increased amounts to replace roughage in adaptation diets showed no detrimental effects on performance due to high sulfur levels (Rolfe, 2010; Sarturi, 2011). The use of phosphoric acid in ethanol production has been studied as an alternative to sulfuric acid, because of its safety in ethanol production and animal consumption. Although this inclusion was successfully substituted chemically, the amount and cost of inclusion of phosphoric acid limits the feasibility of its use (Vanness, 2009).

Performance

Since the expansion of the ethanol industry, and increased availability of by-products, a great deal of research has been conducted to quantify the effects of by-products on beef cattle performance compared to conventional feed sources. As previously mentioned, by-product feeds are an excellent protein and energy source, but similar to other feedstuffs, they present limitations regarding grain source and inclusion level. The use of by-product feeds fed in combination with traditional grain sources such as DRC have shown improved cattle performance as compared to traditional grain sources alone. (Larson et al., 1993; Ham et al., 1994). For example, Ham et al. (1994) observed that steers fed a 40% wet distillers by-product diet were 18.8% more efficiency than steers fed only DRC. Furthermore, Al Suwaiegh et al. (2002) observed that cattle fed diets containing 30% corn distiller's grains in combination with DRC gained 10.1% faster and were 8.5% more efficient than those fed only DRC. More recently, Corrigan et al. (2007) observed enhanced performance of cattle consuming WDGS at inclusion levels of 40, 27.5, and 15% when fed in combination with DRC, HMC, and SFC, respectively.

Research also indicates a quadratic response in cattle performance for inclusion of WDGS in feedlot finishing diets (Firkins et al., 1985; Depenbusch et al., 2009; Quinn et al., 2011). For instance, Loza et al. (2005) observed cattle consuming a combination of WDGS and WCGF at 25 and 50% inclusion had significantly increased DMI and ADG compared to cattle consuming 0 and 75%.

Dry milling plants have the ability to utilize grain sources in addition to corn. However, evidence has shown grain source flexibility has the potential for feeding value of by-products to be affected (Lodge et al., 1997a). A study comparing corn and sorghum distiller's grains to DRC directed by Fanning et al. (1997) showed similar significant improvements in cattle performance. Steers fed corn or sorghum distiller's grains gained 9.8% faster and were 9.1% more efficient, resulting in significantly heavier carcass weights than cattle fed DRC. Similar results were observed by Firkins et al. (1985) comparing distillers grains to high moisture corn (HMC). In this study, calves consuming 42.5% WDGS had significantly greater gains and improved efficiencies compared to cattle fed an 85% concentrate diet of HMC. However, research results in a feeding trial comparing steam flaked corn (SFC) to steam flaked sorghum (SFS) showed that SFS significantly decreased gains in cattle by 6.1% compared to SFC (Zinn, 1991).

Specific research has also focused on comparative nutrient values of wet and dry forms of by-products. Trials have shown improved feed efficiency in cattle fed wet distillers grains compared to those cattle fed a dry distillers by-product (Ham et al., 1994; Lodge et al., 1997a). Decreased performance of DDGS compared to WDGS is most likely due to decreased NE_g values caused by drying procedures in the by-product production process. However, feeding values of dry by-products such as DDGS still often exceed energy values of corn alone. For example, Buckner et al. (2008) observed ADG and feed efficiency responded quadratically to inclusion of DDGS in finishing diets compared to only DRC, optimizing at 20 percent DDGS inclusion.

EFFECT OF ETHANOL BYPRODUCTS ON INCIDENCE/SEVERITY OF ACIDOSIS

Effect, incidence, and severity of acidosis

As mentioned previously, acidosis is a potential common ailment of cattle consuming high concentrate finishing diets. Research has shown increased performance of cattle fed diets containing by-product feeds. These increases in performance could be due to a decrease in subacute acidosis (Firkins et al., 1985; Larson et al., 1993) due to increased fiber and decreased starch in the diet (Klopfenstein et al., 2008). In addition, changes in the microbial population and increased palatability could also be factors for increased performance (Ham et al., 1994). Feeding by-products also provides the opportunity to alter VFA ratios to favor propionate. Ruminal acetate: propionate have shown to be significantly less in cattle consuming diets containing by-product feeds, reducing the likelihood of subacute acidosis (Ham et al., 1994; Scott, 1998; Vander Pol et al., 2009; Uwituze et al., 2010). However, due to acidity of by-product feeds, ruminal pH often drops to subacidosis levels (ruminal pH < pH 5.6) within a few hours after feeding. For instance, results by Uwituze et al. (2010) observed steers consuming a diet containing DDGS had greater lactate concentrations 8 h immediately following feeding compared to those steers consuming diets without DDGS.

Effect on carcass characteristics

A great amount of research has been conducted to examine interactions of distillers by-product feeds and other grain sources in the diet and their effect on carcass characteristics. Carcass characteristics such as HCW, fat thickness, marbling score, and USDA yield and quality grade have responded positively to inclusion of distillers grains up to 30% in finishing diets (Larson et al., 1993; Lodge et al., 1997b; Al-Suwaiegh et al., 2002; Corrigan, 2007). However, some research indicates distillers grain inclusion in finishing diets may cause significantly decreased HCW, dressing percent (Leibovich et al., 2009), dress yield, longissimuss muscle (LM)

area, and carcass quality grade (Depenbusch et al., 2008). Variable incidence of liver abscesses has been demonstrated in cattle fed distillers grains. Some research indicates no effect of distillers grain inclusion on the presence of liver abscesses (Larson et al., 1993; Lodge et al., 1997b) where other data sets show an increased incidence of liver abscesses in cattle consuming distillers byproducts (Corrigan, 2007). Furthermore, Firkins et al. (1985) observed no significant differences in carcass characteristics of cattle consuming a 50% wet distillers grains diet and cattle fed 80% DRC.

Cattle consuming distillers grains have shown to have a greater proportion of polyunsaturated fatty acids (PUFA) in the carcass. Polyunsaturated fatty acids can be a factor in decreased shelf life and the production of uncharacteristic off-flavors (Roeber et al., 2005; Koger et al., 2010). In response, studies have been conducted to test distillers grains effect on the aspects of retail display, shelf life, and tenderness of beef. Specific research demonstrates no effect on sensory attributes of tenderness, juiciness, or flavor of cattle fed distillers grains (Roeber et al., 2005; Jenschke et al., 2007). However, Roeber et al. (2005) showed significant evidence that shelf life and color stability are unaffected by the inclusion of distillers grains when included in the diet at levels below 20%. Due to the potential detrimental effects on carcass characteristics, a number of research studies and industry reports have recommended distillers grains make up approximately 15 to 20% of finishing diets (Vasconcelos and Galyean, 2007; Depenbusch et al., 2008; Leibovich et al., 2009; Koger et al., 2010)

ADAPTATION

Correct nutritional management of cattle during the adaptation period is critical to subsequent health and performance. Due to the desire for increased economic efficiency, it is common for feedlots to adapt cattle to high-concentrate finishing diets in less than 21 days. This attempt to maximize energy intake causes a rapid shift from primarily fibrolytic to amylolytic

bacteria (Goad et al., 1998) in the rumen increasing the potential for subacute or acute acidosis. Gradual transition of cattle from high roughage to high-concentrate diets is recommended for continuous gain and no long term health effects.

Traditionally, cattle have been adapted to finishing diets by stepping down amounts of roughage while increasing concentrate levels incrementally from 55% to 90% over a period of three to four weeks (Bevans et al., 2005b; Vasconcelos and Galyean, 2007). Two-ration blending, a scheme where proportions of finishing and low-roughage diets are altered continuously throughout a 21 to 25 d period, are also utilized for adaptation (Vasconcelos and Galyean, 2007). Designing adaptation programs is a balancing act between maximizing growth performance while controlling feed intakes and acidosis, taking into consideration animals most susceptible to metabolic disorders (Bevans et al., 2005a). Research also supports increased frequency of feeding during adaptation periods in order to decrease or avoid digestive disturbances (Tremere, 1968).

Use of distillers grains in adaptation programs

The cost and handling characteristics give reason for feedlots to prefer decreased roughage levels in adaptation diets. With increased availability of by-product feeds, there is opportunity to utilize these feedstuffs to replace roughage in adaptation diets for finishing cattle. Increased NDF and decreased starch levels make ethanol by-products a desirable alternative to roughage in adaptation and finishing diets (Klopfenstein et al., 2008) . Research has been conducted to test the value of by-product feeds as substitutes for roughage in adaptation diets (Loza, 2005; Huls, 2009; Rolfe, 2010; Sarturi, 2011). Specifically, Rolfe et al. (2010) found that steers adapted to the finishing diet by decreasing WDGS and increasing DRC had decreased DMI during a 28 d adaptation period. However, no differences in DMI were observed between steers adapted using sequential steps decreasing WDGS and steers adapted using sequential steps decreasing roughage. Similar

results were observed by Sarturi et al. (2011) where cattle adapted to the finishing diet by decreasing WDGS over 28 d had decreased DMI during the first 21 d of adaptation compared to steers adapted by decreasing WCGS during the adaptation period. Also, steers adapted to the finishing diet using decreasing amounts of WDGS ate significantly smaller meals during adaptation and during the finishing period. Research results by Rolfe et al. (2010) and Sarturi et al. (2011) indicate that DMI were decreased when WDGS inclusion exceeded 48%.

SUMMARY

In the past, acidosis has been the most predominant metabolic disorder in the cattle feeding industry. However, through improved understanding of the a variety of factors including feed products, relationship between ruminal factors and metabolic disorders, cattle behavior in response to metabolic events, and feeding programs, the cattle feeding industry will be more equipped to manage metabolic disorders and reduce the economic impact of their effect on the industry.

LITERATURE CITED

Ahrens, F. A. 1967. Histamine, Lactic Acid and Hypertonicity as factors in the Development of Rumenitis. Am. J. Vet. Res. 28: 1335.

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002. Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim Sci. 80: 1105-1111.

AlZahal, O., E. Kebreab, J. France, M. Froetschel, and B. W. McBride. 2008. Ruminal Temperature May Aid in the Detection of Subacute Ruminal Acidosis. J. Dairy Sci. 91: 202-207.

AlZahal, O., M. A. Steele, E. V. Valdes, and B. W. McBride. 2009. Technical note: The use of a telemetric system to continuously monitor ruminal temperature and to predict ruminal pH in cattle. J. Dairy Sci. 92: 5697-5701.

Bartel, S. J. and R. L. Preston. 1992. Roughage level and limited maximum intake regimens for feedlot steers. J. Anim. Sci. 70(11): 3293-3303.

Bauer, M. L., D. W. Herold, R. A. Britton, R. A. Stock, T. J. Klopfenstein, and D. A. Yates. 1995. Efficacy of laidlomycin propionate to reduce ruminal acidosis in cattle. J. Anim Sci. 73: 3445-3454.

Beharka, A. A., T. G. Nagaraja, J. L. Morrill, G. A. Kennedy, and R. D. Klemm. 1998. Effects of Form of the Diet on Anatomical, Microbial, and Fermentative Development of the Rumen of Neonatal Calves. J. Dairy Sci. 81: 1946-1955.

Bergen, W. G., and D. B. Bates. 1984. Ionophores: Their Effect on Production Efficiency and Mode of Action. J. Anim Sci. 58: 1465-1483.

Bergman, E. N. 1990. Energy contributions of volatile fatty acids from the gastrointestinal tract in various species. Physiol. Rev. 70: 567-590.

Bevans, D. W., K. A. Beauchemin, K. S. Schwartzkopf-Genswein, J. J. McKinnon, and T. A. McAllister. 2005a. Effect of rapid or gradual grain adaptation on subacute acidosis and feed intake by feedlot cattle. J. Anim Sci. 83: 1116-1132.

Bevans, D. W., K. A. Beauchemin, K. S. Schwartzkopf-Genswein, J. J. McKinnon, and T. A. McAllister. 2005b. Effect of rapid or gradual grain adaptation on subacute acidosis and feed intake by feedlot cattle. J. Anim Sci. 83: 1116-1132.

Britton, R. A., and R. A. Stock. (1987). Acidosis, Rate of Starch Digestion and Intake. In: Symposium Proceedings: Feed Intake by Beef Cattle. Stillwater, OK, Oklahoma State University. MP-121: 125.

Brown, H., R. F. Bing, H. P. Grueter, J. W. McAskill, C. O. Cooley, and R. P. Rathmacher. 1975. Tylosin and Chlortetracycline for the Prevention of Liver Abscesses, Improved Weight Gains and Feed Efficiency in Feedlot Cattle. J. Anim Sci. 40: 207-213.

Brown, M. S., C. R. Krehbiel, M. L. Galyean, M. D. Remmenga, J. P. Peters, B. Hibbard, J. Robinson, and W. M. Moseley. 2000. Evaluation of models of acute and subacute acidosis on dry matter intake, ruminal fermentation, blood chemistry, and endocrine profiles of beef steers. J. Anim Sci. 78: 3155-3168.

Buckner, C. D., T. L. Mader, G. E. Erickson, S. L. Colgan, D. R. Mark, V. R. Bremer, K. K. Karges, and M. L. Gibson. Evaluation of Dry Distillers Grains Plus solubles Inclusion on Performance and Economics of Finishing Beef Steers. Professional Animal Scientist. 24(2008):404-410.

Burrin, D. G., and R. A. Britton. 1986. Response to Monensin in Cattle during Subacute Acidosis. J. Anim Sci. 63: 888-893.

Byers, F. M., G.T. Schelling. 1993. The Ruminant Animal Digestive Physiology and Nutrition. Waveland Press, Long Grove, IL.

Carter, R. R., and W. L. Grovum. 1990. A review of the physiological significance of hypertonic body fluids on feed intake and ruminal function: salivation, motility and microbes. J. Anim Sci. 68: 2811-2832.

Center, A. M. R. 2011. Fuel and Grian Historic Comparisons. United States Department of Agriculture.

Cooper-Prado, M. J., N. M. Long, E. C. Wright, C. L. Goad, and R. P. Wettemann. 2011. Relationship of ruminal temperature with parturition and estrus of beef cows. J. Anim Sci. 89: 1020-1027.

Cooper, R., T. Kopfenstein, R. Stock and C. Parrott. 1998. Observations on acidosis through continual feed intake and ruminal pH monitoring. .

Cooper, R. J., T. J. Klopfenstein, R. A. Stock, C. T. Milton, D. W. Herold, and J. C. Parrott. 1999. Effects of imposed feed intake variation on acidosis and performance of finishing steers. J. Anim Sci. 77: 1093-1099.

Corrigan, M. E., G. E. Erickson, T. J. Klopfenstein, K. J. Vander Pol, M. A. Greenquist, and M. K. Luebbe. 2007. Effect of Corn Processing and Wet Distillers Grains Inclusion Level in Finishing Diets, University of Nebraska, Lincoln, NE.

Crawford, G. I., C. D. Keeler, J. J. Wagner, C. R. Krehbiel, G. E. Erickson, M. B. Crombie, and G. A. Nunnery. 2008. Effects of calcium magnesium carbonate and roughage level on feedlot performance, ruminal metabolism, and site and extent of digestion in steers fed high-grain diets. J. Anim Sci. 86: 2998-3013.

Depenbusch, B. E., C. M. Coleman, J. J. Higgins, and J. S. Drouillard. 2009. Effects of increasing levels of dried corn distillers grains with solubles on growth performance, carcass characteristics, and meat quality of yearling heifers. J. Anim Sci. 87: 2653-2663.

Depenbusch, B. E., J. S. Drouillard, E. R. Loe, J. J. Higgins, M. E. Corrigan, and M. J. Quinn. 2008. Efficacy of monensin and tylosin in finishing diets based on steam-flaked corn with and without corn wet distillers grains with solubles. J. Anim Sci. 86: 2270-2276.

Eadie, J. M., and S. O. Mann. . 1970. Debelopment of the rumen microbial population: High starch diets and instability. . In: A. T. Phillipson (ed.) Physiology of Digestion and Metabolism in the Ruminant. p 335 - 347. Oriel Press, Newcastle Upon Tyne, U.K.

Erickson, G. E., C. T. Milton, K. C. Fanning, R. J. Cooper, R. S. Swingle, J. C. Parrott, G. Vogel, and T. J. Klopfenstein. 2003. Interaction between bunk management and monensin concentration on finishing performance, feeding behavior, and ruminal metabolism during an acidosis challenge with feedlot cattle. J. Anim Sci. 81: 2869-2879.

Erickson, G. E., T.J. Klopfenstein, D.C. Adams, R.J. Rasby. General Overview of Feeding Corn Milling Co-Procucts to Beef Cattle

Corn Processing Co-Products Manual, A Review of Current Research on Distillers Grains and Corn Gluten. p 3 - 12. University of Nebraska-Lincoln.

Fanning, K., T. Milton, T. Klopfenstein, and M. Klemesrud. 1999. Corn and sorghum distillers grains for finishing cattle, Lincoln, NE.

Firkins, J. L., L. L. Berger, and G. C. Fahey. 1985. Evaluation of Wet and Dry Distillers Grains and Wet and Dry Corn Gluten Feeds for Ruminants. J. Anim Sci. 60: 847-860.

Goad, D. W., C. L. Goad, and T. G. Nagaraja. 1998. Ruminal microbial and fermentative changes associated with experimentally induced subacute acidosis in steers. J. Anim Sci. 76: 234-241.

Gramlish, S. M., R. T. Brandt, Jr. and R. V. Pope. 1990. Dose response to supplemental fat by finishing steers. Kansas Agric. Exp. Sta. Rep. of Prog. 592. P 4. Manhattan.

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grains with solubles as a source of protein and energy for ruminants. J. Anim Sci. 72: 3246-3257.

Hinders, R. G., and F. G. Owen. 1965. Relation of Ruminal Parakeratosis Development to Volatile Fatty Acid Absorption. J. Dairy Sci. 48: 1069-1073.

Huffman, R. P., R. A. Stock, M. H. Sindt, and D. H. Shain. 1992. Effect of fat type and forage level on performance of finishing cattle. J. Anim Sci. 70: 3889-3898.

Huls, T. J., M. K. Luebbe, W. A. Griffin, G. E. Erickson, T. J. Klopfenstein, R. A. Stock. 2009. Using Wet Corn Gluten Feed to Adapt Cattle to Finishing Diets, University of Nebraska, Lincoln, NE.

Jenschke, B. E., J. M. James, K. J. Vander Pol, T. J. Klopfenstein, and C. R. Calkins. 2007. WET Distillers grains plus solubles do not increase liver-like-off-flavors in cooked beef from yearling steers. J. Muscle Foods 18: 341-348.

Klopfenstein, T. J., G. E. Erickson, and V. R. Bremer. 2008. BOARD-INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. J. Anim Sci. 86: 1223-1231.

Koger, T. J., D. M. Wulf, A. D. Weaver, C. L. Wright, K. E. Tjardes, K. S. Mateo, T. E. Engle, R. J. Maddock, and A. J. Smart. 2010. Influence of feeding various quantities of wet and dry distillers grains to finishing steers on carcass characteristics, meat quality, retail-case life of ground beef, and fatty acid profile of longissimus muscle. J. Anim Sci. 88: 3399-3408.

Krehbiel, C. R., R. A. Britton, D. L. Harmon, T. J. Wester, and R. A. Stock. 1995a. The effects of ruminal acidosis on volatile fatty acid absorption and plasma activities of pancreatic enzymes in lambs. J. Anim Sci. 73: 3111-3121.

Krehbiel, C. R., R. A. Stock, D. H. Shain, C. J. Richards, G. A. Ham, R. A. McCoy, T. J. Klopfenstein, R. A. Britton, and R. P. Huffman. 1995b. Effect of level and type of fat on subacute acidosis in cattle fed dry-rolled corn finishing diets. J. Anim Sci. 73: 2438-2446.

Larson, E. M., R. A. Stock, T. J. Klopfenstein, M. H. Sindt, and R. P. Huffman. 1993. Feeding value of wet distillers byproducts for finishing ruminants. J. Anim Sci. 71: 2228-2236.

Leibovich, J., J. T. Vasconcelos, and M. L. Galyean. 2009. Effects of corn processing method in diets containing sorghum wet distillers grain plus solubles on performance and carcass characteristics of finishing beef cattle and on in vitro fermentation of diets. J. Anim Sci. 87: 2124-2132.

Lodge, S., R. Stock, T. Klopfenstein, D. Herold. 1996. Digestibility of Wet and Dry Distillers Grains from the Fermentation of Corn or Sorghum, University of Nebraska, Lincoln, NE.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997a. Evaluation of corn and sorghum distillers byproducts. J. Anim Sci. 75: 37-43.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997b. Evaluation of wet distillers composite for finishing ruminants. J. Anim Sci. 75: 44-50.

Loy, T., T. Klopfenstein, G. Erickson, and C. Macken. 2003. Evaluation of DDGS in High Forage Diets and Effect of Supplementation Frequency. University of Nebraska, Lincoln, Nebraska.

Loza, P. L., K. J. Vander Pol, G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2005. Effects of feeding a By-Product Combination consisting of Wet Distillers Grains and Wet Corn Gluten Feed to Feedlot Cattle, University of Nebraska, Lincoln, NE.

Ludden, P. A., M. J. Cecava, and K. S. Hendrix. 1995. The value of soybean hulls as a replacement for corn in beef cattle diets formulated with or without added fat. J. Anim Sci. 73: 2706-2711.

Lunn, D. E., T. Mutsvangwa, N. E. Odongo, T. F. Duffield, R. Bagg, P. Dick, G. Vessie, and B. W. McBride. 2005. Effect of monensin on meal frequency during sub-acute ruminal acidosis in dairy cows. Can. J. Anim. Sci. 85: 247-249.

Mader, T. L., J. B. Gaughan, and B. A. Young. 1999. Feedlot Diet Roughage Level for Hereford Cattle Exposed to Excessive Heat Load1. Prof. Anim. Sci. 15: 53-62.

Mader, T. L., S. M. Holt, G. L. Hahn, M. S. Davis, and D. E. Spiers. 2002. Feeding strategies for managing heat load in feedlot cattle. J. Anim Sci. 80: 2373-2382.

Morris, S. E. 2005. The Effects of Dried Distillers Grains on Heifers Consuming Low or High Quality Forage, University of Nebraska, Lincoln, NE.

Nagaraja, T. G., T. B. Avery, E. E. Bartley, S. J. Galitzer, and A. D. Dayton. 1981. Prevention of Lactic Acidosis in Cattle by Lasalocid or Monensin. J. Anim Sci. 53: 206-216.

NRC. 1980. Mineral Tolerance of Domestic Animals. National Academy of Sciences, Washington D.C.

NRC. 2000. Minerals 7th ed. ed. Natl. Acad. Press, Washington, DC.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: a review. J. Anim Sci. 76: 275-286.

Owens, F. N. and A. L. Goetsch. 1993. The Ruminant Animal Digestive Physiology and Nutrition. Waveland Press, Inc., Long Grove, IL.

Parsons, C. H., J. T. Vasconcelos, R. S. Swingle, P. J. Defoor, G. A. Nunnery, G. B. Salyer, and M. L. Galyean. 2007. Effects of wet corn gluten feed and roughage levels on

performance, carcass characteristics, and feeding behavior of feedlot cattle. J. Anim Sci. 85: 3079-3089.

Quinn, M. J., M. L. May, N. DiLorenzo, C. H. Ponce, D. R. Smith, S. L. Parr, and M. L. Galyean. 2011. Effects of roughage source and distillers grain concentration on beef cattle finishing performance, carcass characteristics, and in vitro fermentation. J. Anim Sci. 89: 2631-2642.

Roeber, D. L., R. K. Gill, and A. DiCostanzo. 2005. Meat quality responses to feeding distiller's grains to finishing Holstein steers. J. Anim Sci. 83: 2455-2460.

Rolfe, K. M., G. E. Erickson, T. J. Klopfenstein, J. T. Vasconcelos. 2010. Effects of Using Wet Distillers Grains with Solubles to Adapt Cattle to Finishing Diets on Feed Intake, Ruminal pH, and Ruminal Hydrogen Sulfide Concentration, University of Nebraska, Lincoln, NE.

Sarturi, J. O., G. E. Erickson, T. J. Klopfenstein, J. T. Vasconcelos, M. G. Dibb, K. Rolfe. 2011. Effects of Adaptation Diets containing Wet Distillers Grains With Solubles or Wet Corn Gluten Feed on Ruminal pH, Intake and Hydrogen Sulfide, University of Nebraska, Lincoln, NE.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, D. J. Gibb, D. H. Crews, Jr., D. D. Hickman, M. Streeter, and T. A. McAllister. 2003. Effect of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review. J. Anim Sci. 81: E149-158.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, T. A. McAllister, D. J. Gibb, M. Streeter, and A. D. Kennedy. 2004. Effect of feed delivery fluctuations and feeding time on ruminal acidosis, growth performance, and feeding behavior of feedlot cattle. J. Anim Sci. 82: 3357-3365.

Scott, T., T. Klopfen stein, R. Stock, and R. Cooper. . 1998. Metabolism and digestibility of corn bran and corn steep liquor/distillers solubles. . Neb. Beef Cattle Rep. MP 69-A: 69-71.

Service, E. R. 2010. Corn Used for Ethanol: Feed Grains Database Custom Query; Supply and Use, Utilization for Alcohol in Fuel, Corn, United States, Market year, 1986-2010.

Spires, H. R., A. Olmsted, L. L. Berger, J. P. Fontenot, D. R. Gill, J. G. Riley, M. I. Wray, and R. A. Zinn. 1990. Efficacy of laidlomycin propionate for increasing rate and efficiency of gain by feedlot cattle. J. Anim Sci. 68: 3382-3391.

Stalker, L. A., T. J. Klopfenstein, D. C. Adams, and G. E. Erickson. 2004. Urea Inclusion in Forage Based Diets Containing Dried Distillers Grains, University of Nebraska, Lincoln, Lincoln, Nebraska.

Stock, R. A., J. M. Lewis, T. J. Klopfenstein, and C. T. Milton. . 1999. Review of new information on the use of wet and dry milling feed byproducts in feedlot diets. In: Proc. Am. Soc. Anim. Sci.

Stock, R. A., M. H. Sindt, J. C. Parrott, and F. K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim Sci. 68: 3441-3455.

Sutton, J. D., M. S. Dhanoa, S. V. Morant, J. France, D. J. Napper, and E. Schuller. 2003. Rates of Production of Acetate, Propionate, and Butyrate in the Rumen of Lactating Dairy Cows Given Normal and Low-Roughage Diets. J. Dairy Sci. 86: 3620-3633.

Tokgoz, T., A. Elobeid, J. Fabiosa, D. J. Haves, B. A. Babcock, T. H. Yu, F. Dong, C. E. Hart, and J. C. Beghin. 2007. Emerging Biofuels: Outlook of Effects on U. S. Grain, Oilseed, and Livestock Markets.

Tremere, A. W., W.G. Merrill, J.K. Loosli. . 1968. Adaptation to High Concentrate Feeding as Related to Acidosis and Digestive Disturbance in Dairy Heifers. J. Dairy Sci. 51: 1065.

Uwituze, S., G. L. Parsons, M. K. Shelor, B. E. Depenbusch, K. K. Karges, M. L. Gibson, C. D. Reinhardt, J. J. Higgins, and J. S. Drouillard. 2010. Evaluation of dried distillers grains and roughage source in steam-flaked corn finishing diets. J. Anim Sci. 88: 258-274.

Vander Pol, K. J., G.E. Erickson, T.J. Klopfenstein, C.N. Macken. 2004. Effects of Wet and Dry Distillers Grains Plus Solubles and Supplemental Fat Level on Performance of Yearling Finishing Cattle

University of Nebraska, Lincoln, NE.

Vander Pol, K. J., G.E. Erickson, T.J. Klopfenstein. 2005. Degradable Intake Protein in finishing Diets containing Dried Distillers Grains, University of Nebraska, Lincoln, NE.

Vander Pol, K. J., M. K. Luebbe, G. I. Crawford, G. E. Erickson, and T. J. Klopfenstein. 2009. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of corn processing coproducts, or supplemental corn oil. J. Anim Sci. 87: 639-652.

Vanness, S. J., T. J. Klopfenstein, G. E. Erickson, K. K. Karges. 2009. Sulfur in Distiller's Grains, University of Nebraska, Lincoln, NE.

Vasconcelos, J. T., and M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim Sci. 85: 2772-2781.

Waller, J., T. Klopfenstein, and M. Poos. 1980. Distillers Feeds as Protein Sources for Growing Ruminants. J. Anim Sci. 51: 1154-1167.

Wilken, M. E., M. K. Luebbe, G. E. Erickson, T. J. Klopfenstein, J. R. Benton. 2009. Effects of Feeding Hihg Levels of Byproducts in Different Combinations to Finishing Steers, University of Nebraska, Lincoln, NE.

Yokoyama, M. T., and K. A. Johnson. 1993. The Ruminant Animal Digestive Physiology and Nutrition. Waveland Press, Long Grove, IL.

Zinn, R. A. 1989. Influence of Level and Source of Dietary Fat on Its Comparative Feeding Value in Finishing Diets for Feedlot Steers: Metabolism. J. Anim Sci. 67: 1038-1049.

Zinn, R. A. 1991. Comparative feeding value of steam-flaked corn and sorghum in finishing diets supplemented with or without sodium bicarbonate. J. Anim Sci. 69: 905-916.

CHAPTER III

A COMPARISON OF TWO DIETS AND TWO METHODS OF ADAPTATION ON FEEDLOT CATTLE PERFORMANCE

ABSTRACT: One hundred forty-four steers were used to evaluate the effects of two diets and two adaptation methods over a 28 d period of adaptation to the finishing diet. Steers were blocked by weight and assigned to feedlot pens. Pens were randomly assigned to one of four treatments: traditional diet (TRAD) using the forage step-down (STEP) method, TRAD diet using the two-ration blending (2RB) method, wet distiller's grains with solubles (WDGS) diet (DG) using a WDGS step-down method (STEP), and DG diet using the 2RB method. Wet distiller's grains with solubles and dry rolled corn (DRC) were increased and roughage was decreased in TRAD using STEP by sequential changes of 60%, 70%, and 80% concentrate. The finishing diet was increased while the 60% concentrate diet of TRAD was decreased in daily incremental changes with TRAD using 2RB. The quantity of WDGS was decreased at levels from 84%, to 66%, to 48% and DRC was increased from 0.0%, to 18% and finally to 36% in DG using STEP. In DG using 2RB, WDGS was decreased in daily incremental changes while the inclusion of the finishing diet increased. During the 28 d adaptation period, steers were fed twice daily in proportions of each treatment according to STEP or 2RB adaptation methods. All steers received a 90% concentrate finishing ration from d 28 to the end of the feeding period. Performance data

was analyzed as a randomized complete block design with weight block included as a random effect. Treatments were assigned in a 2 x 2 factorial arrangement with pen as the experimental unit. During adaptation, steers fed DG had lower ($P < 0.01$) BW, DMI, ADG, and G:F than steers fed TRAD. Over the entire feeding period, steers fed DG adapted using STEP and those fed TRAD adapted using 2RB had greater ADG compared to steers fed TRAD adapted using STEP and steers fed DG adapted using 2RB ($P < 0.01$). Greater DMI were achieved for steers fed TRAD compared to steers fed DG ($P < 0.01$), however, there was no effect of adaptation diet or method on feed efficiency during the entire feeding period ($P \leq 0.71$). Steers adapted using STEP had greater marbling scores compared to steers adapted using 2RB ($P = 0.04$). Results show diet type has an effect on the best method of adaptation; however, sulfur levels of the DG diet may have played a role in decreased performance. Steers fed DG during adaptation recovered in the subsequent feed period, performing similar to steers adapted using TRAD.

INTRODUCTION

In the cattle feeding industry, increased costs for dietary ingredients presents unrelenting pressure for increased economic efficiency. Cattle newly introduced to the feedlot often have compromised health status and minimal exposure to feed bunks potentially causing inadequate and variable nutrient intake. These factors have a deleterious effect on the ruminal environment making a period of adaptation essential to adjust ruminal microorganisms from a typical forage-based diet to one that contains a high level of concentrate. Too rapid an adjustment to a grain based diet can cause cattle to experience a variety of metabolic disorders which have the potential to negatively affect subsequent feedlot performance (Brown et al., 2006).

Costs and handling characteristics provide reason for the feeding industry to minimize the use of roughages in diets. On average, approximately 40 percent roughage is utilized during the adaptation period, accounting for a large portion of total roughage use and therefore total feed costs during the entire feeding period (Vasconcelos and Galyean, 2007). Alternative methods of adaptation provide the opportunity to decrease roughage and improve efficiency of feeding schedule compared to traditional

adaptation methods while incorporating reduced cost feed ingredients. In the past few years, byproduct feeds have become a highly used cost-efficient source of energy and protein in finishing diets, however, inflated NDF and decreased starch levels make byproducts a desirable alternative to roughage in diets used to adapt cattle to the finishing diet (Klopfenstein et al., 2008).

Limited published adaptation research is available comparing traditional adaptation diets and methods to those adaptation diets now incorporating byproducts. Therefore, the objective of this experiment was to compare the performance of steers fed a traditional or wet distiller's grains with solubles (WDGS) adaptation diet utilizing two different adaptation methods.

MATERIALS AND METHODS

Animals and dietary treatments

One hundred forty-four mixed breed beef steers were blocked by weight and randomly assigned to feedlot pens containing six steers per pen. Within block, pens were randomly assigned to one of four dietary treatments (Table 3.1). On d 0, steers in blocks 1, 2, and 3 were implanted with Revalor-IS (Merck Animal Health, Whitehouse Station, NJ) and steers in blocks 4, 5, and 6 were implanted with Revalor-S (Merck Animal Health). Blocks 1, 2, and 3 were re-implanted on d 84 with Revalor-S (Merck Animal Health). All diets were formulated to meet NRC (2000) requirements for vitamins and minerals. All contained 6.0% supplement (Table 3.1) which contained monensin (Rumensin 80, Elanco Animal Health, Greenfield, IN), tylosin (Tylan 40, Elanco Animal Health, Greenfield, IN) at 36 and 11 mg/kg (90 % DM basis), respectively. Diets were prepared fresh daily in a feed mixer and delivered at 0730 and 1330 to provide ad libitum consumption.

During the 28 d adaptation period, steers were fed twice daily in proportions of each treatment (Table 3.2). Dietary treatments consisted of a traditional (TRAD) or WDGS diet (DG) using a step (STEP) or two-ration blend (2RB) adaptation method. Dry rolled corn (DRC) and WDGS were increased and roughage was decreased in TRAD adaptation diets 1, 2, and 3 using the STEP adaptation level. In the

TRAD diet using the 2RB adaptation method, the ratio of finishing diet to diet 1 of the TRAD adaptation diet was increased in daily incremental changes over 21 d. The quantity of WDGS was decreased from 84, 66, and 48% through DG adaptation diet steps 1, 2, and 3 and DRC was increased from 0.0, 18 and 36% while forage was held constant at 10% using the STEP adaptation method. In the DG diet using the 2RB adaptation method, the ratio of finishing diet to diet 1 of the DG adaptation diet was increased in daily incremental changes over 21 days. All steers received a common 90% concentrate finishing ration from d 22 through 28 of adaptation and during finishing period. Cattle received zilpaterol hydrochloride (Zilmax, Intervet/Shering-Plough, Millsboro, DE) at 90 mg/hd/d for 20 d starting 24 d prior to the end of the finishing period.

Feed intake and body weight

Amounts of feed offered were recorded daily. During adaption, dietary samples from feed bunks were collected daily at 1500 for determination of DM and dietary consistency and were kept in dry storage for later chemical analysis. Chemical analyses of dietary samples collected daily during adaptation are listed in Table 3.4. During the finishing period, orts were collected daily and dietary samples were collected weekly for DM determination. After drying, samples were composited by month and kept in dry storage for later analysis. Mean values with standard deviations for samples within the adaptation period are listed in Table 3.4.

On d -1 and 0, steers were given ad libitum access to hay and water. Initial weights were calculated from the average of weights taken before feeding on d -1 and 0. On day 0, steers were processed, blocked by the initial weight and allotted to one of 24 pens. Steers were weighed following adaptation (d 29), on consecutive 28 d intervals during the trial, and at the end of the feeding period for each respective block. Blocks 5 and 6 were fed for 125 d, block 4 was fed for 154 d, and blocks 1, 2, and 3 were fed for 181 d.

Carcass data collection

Carcasses were evaluated by West Texas A&M personnel for marbling score, fat thickness at the 12 rib, LM area, percentage of KPH, and maturity. Dressing percentage and yield grade was calculated, and quality grade was determined from marbling score and carcass maturity. Hot carcass weight, adjusted to a common dressing percentage of 64%, was used to estimate final live weight. Efficiency and ADG were calculated according to final live weight and carcass adjusted final live weight.

Statistical analyses

Feedlot performance and carcass data was analyzed as a complete randomized block design using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), testing for differences resulting from adaptation diet and adaptation method. Pen was the experimental unit and block was included as a random effect. Treatments were assigned in a 2 x 2 factorial arrangement testing effect of TRAD vs. DG diets and STEP vs. 2RB adaptation methods. Differences are discussed when $P \leq 0.05$ and considered tendencies when $0.05 < P \leq 0.10$. Categorical data (Quality and Yield grade data) were analyzed using the GLIMMIX procedure of SAS on a pen basis as binomial proportions using the same model as for continuous variables.

RESULTS

Performance

Feedlot performance data are summarized in Table 4. Analyzed nutrient composition of adaptation diets are listed on Table 3.3. During the adaptation period (d 0 – 28), adaptation method did not affect BW, DMI, ADG, or G:F ($P \leq 0.96$). However, adaptation diet did effect BW, DMI, ADG, and G:F ($P < 0.01$). After the adaptation period, steers on the TRAD diet adapted using STEP and 2RB (381.9 and 381.0 kg) adaptation methods had heavier BW compared to steers on the DG diet adapted using the STEP and 2RB (361.0 and 361.5 kg) adaptation methods. Intake was also greater for steers on the TRAD diet adapted using the STEP and 2RB (7.40 and 7.54 kg/d) adaptation methods compared to steers on the DG diet adapted using the STEP and 2RB (4.63 kg/d) adaptation methods. Greater intakes produced improved ADG for steers on the TRAD diet adapted using the STEP and 2RB (1.01 and .83

kg/d) adaptation methods compared to steers on the DG diet adapted using the STEP and 2RB (0.23 and 0.14 kg/d) adaptation methods. Steers on the TRAD diet adapted using the STEP and 2RB (0.14 and 0.03 kg:kg) adaptation methods also had improved feed efficiency compared to steers on the DG diet adapted using the STEP and 2RB (0.09 and 0.03 kg:kg) adaptation methods.

For the feeding period of d 29 through 56, steers on the TRAD diet had heavier BW compared to steers on the DG diet ($P < 0.01$). Adaptation diet × adaptation method also tended to affect BW ($P = 0.08$) and DMI ($P = 0.10$). There was an interaction of adaptation diet × adaptation method on ADG ($P = 0.03$) where steers on the DG diet gained more using the STEP method and steers on the TRAD diet gained more using the 2RB method compared to steers on the TRAD diet using the STEP and DG diets using the 2RB method. Steers on the DG diet were more efficient compared to steers on the TRAD diet ($P = 0.05$). On d 57 through 84, steers adapted to the finishing diet using the 2RB method had greater BW than steers adapted using the STEP method explained somewhat by a tendency for steers adapted using the 2RB method to have greater DMI than steers adapted using the STEP method ($P = 0.08$). Adaptation diet × adaptation method also tended to effect BW ($P = 0.10$). For this period, ADG and feed efficiency were not affected by adaptation diet or method ($P \leq 0.47$).

From d 84 to the end of the feeding period, steers on the DG diet adapted to the finishing diet using the STEP method and steers on the TRAD diet adapted using the 2RB method had greater BW than steers on the TRAD diet adapted using the STEP method and steers on the DG diet adapted using the 2RB method ($P = 0.03$). Steers adapted to the finishing diet using the STEP method had greater ADG and improved feed efficiency compared to steers adapted using the 2RB method ($P \leq 0.05$). There was no effect of adaptation diet or method on DMI for this period ($P \leq 0.71$).

Final live BW showed an interaction of adaptation diet × adaptation method; steers on the TRAD diet adapted to the finishing diet using the 2RB method and steers on the DG diet adapted using the STEP method having greater final live BW compared to steers on the TRAD diet adapted using the STEP

method and steers on the DG diet adapted using the 2RB method ($P = 0.03$), however, there was no difference in carcass adjusted final live weight ($P = 0.81$). Over the entire feeding period, steers on the DG diet adapted to the finishing diet using the STEP method and those on the TRAD diet adapted using the 2RB method had greater ADG compare to steers on the TRAD diet adapted using the STEP method and those on the DG diet adapted using the 2RB method ($P < 0.01$), however there was no difference in carcass adjusted ADG ($P = 0.80$). Greater DMI were achieved for steers adapted with the TRAD diet compared steers adapted with the DG diet ($P < 0.01$), however, there was no effect of adaptation diet or method on feed efficiency during the entire feeding period ($P \leq 0.71$). Nevertheless, there was a tendency for steers on the DG diet to have improved carcass adjusted G:F compared to steers on the TRAD diet during adaptation ($P = 0.10$).

Carcass characteristics

The interaction of adaptation diet × adaptation method caused steers on the TRAD diet adapted to the finishing diet using the STEP method and steers on DG diet adapted using the 2RB method had greater dressing percentage compared to steers on TRAD diet adapted using 2RB and steers on DG diet using STEP during adaptation ($P < 0.01$). Dressing percentage was the only carcass characteristic to show an interaction; for this reason, main effects of finishing diet adaptation diet on carcass traits are summarized in Table 3.5 and the main effects of finishing diet adaptation method on carcass traits are summarized in Table 3.6.

Adaptation diet had no effect on carcass traits ($P \leq 0.65$) or distribution of USDA quality and yield grades ($P \leq 0.80$) and calculated quality and yield grades ($P \leq 0.97$). Adaptation method had no effect on HCW, LM area, 12^{th} rib fat thickness, KPH %, or calculated yield grade ($P \leq 0.68$); however, steers adapted using the STEP method had greater marbling scores compared to steers adapted using the 2RB adaptation method ($P = 0.04$). Adaptation method affected the distribution of USDA yield grades, where steers adapted to the finishing diet using the 2RB method tended to have a greater percentage of

USDA yield grade 1 carcasses ($P = 0.09$) compared to steers adapted using the STEP method. All other USDA yield grade categories were not affected by adaptation method ($P = 0.94$).Adaptation method did not have an effect on the percentage of USDA quality grade carcasses ($P \leq 0.44$). Steers adapted using the 2RB method had a greater percentage of carcasses with ≤ 1.99 calculated yield grade ($P = 0.01$). Conversely, steers adapted to the finishing diet using the STEP method had a greater percentage of carcasses with 2.5 to 2.99 calculated yield grade ($P = 0.03$). All other calculated yield grade categories were not affected by adaptation method ($P = 0.96$).

DISCUSSION

Performance

The basis for decreased performance of steers fed the DG diet during adaptation could be contributed by a combination of factors including high sulfur, low pH of WDGS, and roughage content in this diet. Rolfe et al. (2010) and Sarturi et al. (2011) utilized WDGS to adapt cattle using a similar protocol to the present study. They found that cattle adapted to finishing diets with by-product feeds had lower DMI during the adaptation period but no differences in overall finishing performance were observed. Data presented by Larson et al. (1993) also showed decreased intakes in yearling and calf-fed steers as inclusion rate of wet distillers grains increased from 0 to 40%, however steers fed increasing levels of wet distillers grains were more efficient than those fed a DRC based control diet.

Nutritional guidelines recommend sulfur levels at 0.15 % for beef cattle (NRC, 2000) with a maximum tolerance concentration at 0.40 % (NRC, 1980). In the present study, sulfur content of all four adaptation diets exceeded maximum tolerance recommendations. The DG diet contained 0.71 and 0.58% sulfur for the STEP and 2RB methods, respectively; being 0.25 and 0.11% units greater than the STEP (0.46%) and 2RB (0.47%) methods of the TRAD diet (Table 5). The TRAD diet also included WDGS, but to a lesser extent than the DG diet, being the reason for relatively high sulfur levels in those adaptation diets as well. Rolfe et al. (2010) and Sarturi et al. (2011) analyzed ruminal hydrogen sulfide

concentrations in steers being adapted to the finishing diet using WDGS. Their research findings concluded that decreased DMI during the adaptation period of steers fed a WDGS based adaptation diet could be due to sulfur content of the diet.

A performance summary by Vanness et al. (2009) analyzed the incidence of polioencephalomacia (PEM) in cattle consuming diets with a high inclusion of by-products. The results of this analysis revealed increased incidence of PEM in cattle when diets containing greater than 0.46% sulfur and 50% WDGS were fed. Vanness also pointed out that the amount of time to use a load of WDGS is increased in a research feed yard compared to a commercial feed yard, so a load with high sulfur level would be fed for an extended period of time potentially increasing the PEM incidence. Larger feed yards feed multiple loads of WDGS each day, potentially diluting out high sulfur levels. In the present study, sulfur levels within the DG diets exceeded levels recommended by Vanness and the NRC, most likely causing the decrease in DMI during the adaptation period. Prolonged use of WDGS from a particular load high in sulfur could have had an effect on DMI and the incidence of PEM compared to steers consuming a diet containing less WDGS, however no PEM cases were observed in steers on the DG or TRAD diets in the present study.

Unpublished data by Christensen et al. (2011) showed that cattle intrauminally dosed with a combination of WDGS and DRC reached subacute acidosis levels faster and remained at a lower ruminal pH level than cattle dosed with only DRC. Christensen attributed the low ruminal pH to WDGS having a pH potentially less than 4.0 (IBC, 2008). Research conducted by Firkins et al. (1985) suggested that increased feed efficiency when wet distiller's grains were fed may have been due in part to a reduction in subacute acidosis. In the present study, cattle on the DG diet were most likely experiencing some level of acidosis due to decreased ruminal pH caused more by the influx of acid from the WDGS rather than the amount of starch in the diet. Specifically, steers on the DG diet performed numerically better during adaptation when using the 2RB adaptation method. This was most likely due to an incremental change in diet each day with the 2RB method compared to a 7 d period on a single diet high in WDGS with the

STEP adaptation method. These factors had the potential to play a role in decreasing DMI during the adaptation period in cattle on DG diet compared to steers on the TRAD diet.

Roughage inclusion within each of the protocols may have also played a role in steer performance during the adaptation period. Steers on the TRAD diet adapted using the STEP method, roughage was decreased in steps of 40, 30, and 20%. The TRAD adaptation diet incorporated into the 2RB method alternated the first step of the TRAD diet containing 60% concentrate and 40% roughage diet with the finisher which contained 90% concentrate (concentrate portion of the finisher contained 54% DRC and 30% WDGS) and 10% roughage. Both adaptation methods of the DG diet contained constant 10% roughage throughout adaptation. Decreased amounts of roughage inclusion within the DG diet may have contributed to a potential decrease in ruminal pH causing decreased DMI and decreased performance of steers during the adaptation period

Evidence of correlation between chronic acidosis and reduced feed intake is present in various research studies (Fulton et al., 1979; Schwartzkopf-Genswein et al., 2003; Schwartzkopf-Genswein et al., 2004). An adaptation study by Bevans et al. (2005) indicated variability of intake in both adaptation protocols providing evidence that animal variability rather than adaptation methodology may play a more significant role in transition to a finishing diet. Cattle who are able to mediate their intake during progressive dietary increases in concentrate during adaptation consume more feed during the succeeding feeding period (Bevans et al., 2005b). In the present study, steers fed the DG diet during adaptation consumed significantly less feed during the adaptation period compared to steers on the TRAD diet due to a variety of factors previously discussed. After steers on the DG diet were adapted to the finishing diet, however, feed intake was similar to steers that consumed the TRAD diet during adaptation, supported by the lack of difference in DMI during the finishing period.

The increase of DMI following adaptation caused steers on the DG diet to achieve a certain level of compensatory gain in the following feeding periods. Additionally, there is a possibility that steers on

the DG diet increased feed intake during periods following adaptation because the ingredients of the finishing diet caused less of a reduction in ruminal pH compared to the DG diet during adaption.

In the present study, performance results of the entire feeding period agree with previous research where cattle adapted to the finishing diet using a high level of concentrate had reduced and variable intakes during adaptation causing reduced gains and efficiency compared to cattle adapted using a more traditional adaptation diet (Bartle and Preston, 1992; Choat et al., 2002; Rolfe, 2010). Analysis of the entire feeding period, however, found DMI of cattle adapted using a high level of concentrate was reduced; however, efficiency was similar when compared to cattle adapted using a traditional diet.

After d 54 of the finishing period, the 2RB adaptation method played a significant role in improved performance of cattle on both the TRAD and DG diets. Conversely, when tested using DRC and dried distillers grains with solubles (DDGS) based adaptation and finishing diets, Burken et al. (2010) found no difference in performance of cattle adapted using the STEP or 2RB methods of adaptation. The form of by-product within these studies may have played a role in the contrasting results.

Holland et al. (2007) tested growth performance and health of steers adapted to the finishing diet using four methods and discovered that a period of feeding a high roughage receiving diet approximately three weeks before implementing the adaptation procedure had positive effects on performance and health. Over the entire feeding period, ADG was greatest for steers with delayed adaptation followed by cattle adapted using step-up and limit feeding methods. In the past, forage costs have been high compared to concentrate sources, however the increase in grain prices within the past year may provide opportunities to improve performance of newly received calves by providing a high roughage diet prior to adaptation.

According to Pritchard and Bruns (2003), cyclic patterns of higher and lower daily DMI can cause gain efficiency to be less than predicted from the average DMI because responses in ADG to changes in DMI are not linear. Cooper et al. (1998) found that deliberate fluctuations in feed intake

caused ruminal pH levels to be lower compared to steers receiving constant amounts of feed. In contrast, results by Schwartzkop-Genswein et al. (2004) found no difference in ADG or feed efficiency of steers whose feed delivery was fluctuated compared to steers fed at a constant rate. In a limit or restricted feeding system, daily intake remains consistent and over-consumption events are controlled. Research evidence has shown tendencies for improvement in feedlot performance during the finishing period for cattle limit-fed during adaptation (Choat et al., 2002; Pritchard and Bruns, 2003; Holland, 2007). In the present study, performance of steers on the DG diet during adaptation give reason to believe that a limit or restricted method of feeding would aid in reducing feed intake variability and moderate ruminal pH during adaptation, allowing them to perform more efficiently in the subsequent feeding period.

A survey conducted by Vasconcelos and Galyean (2007) found that 75% of surveyed nutritionists within the survey utilized 'step-up' methods to adapt cattle to a finishing diet. This particular method requires three to five transition diets being fed three to seven days each during the adaptation period. Increased accuracy of feeding on days when diet changes occur is critical to a smooth transition to the finishing diet. In the present study, increased gains and improved efficiency was observed in steers on the DG diet adapted to the finishing diet using the STEP method.

The two-ration blending adaptation method reported less frequent use (14%) (Vasconcelos and Galyean, 2007), however, this method should reduce the complexity of and number of loads required in the feed yard per day. The reduction in load number within a feed yard will also depend on the type of concentrate included in the diet. In the present study, a majority of concentrate within the TRAD diet was DRC compared to the DG diet which contained WDGS as the primary component initially during the adaptation period. Due to low DM content (approximately 30 to 40% DM), WDGS inclusion as the primary component in a two-ration blending adaptation program may not aid in reducing the number of loads per day due to the feed bulk compared to DRC. More intensive management is required to monitor feeding two different rations in one day (Krehbiel, 2006; Burken, 2010) compared to traditional methods. This adaptation method also assumes that all cattle in a pen consume equal proportions of each ration

daily. This assumption would not be correct since groups of cattle exhibit biological variation (Krehbiel, 2006). Smaller changes in roughage and energy throughout the adaptation period should promote a smoother transition of microbial populations in the rumen to the finishing diet compared to the step-up adaptation method. This was true in the present study where steers on the TRAD diet adapted using the 2RB method gained more and were more efficient in the finishing period.

Through a series of adaptation studies on dairy heifers, Tremere et al. (1968) found that use of a step-up adaptation program caused a consistent reduction in feed intake at a level of 70 to 75% concentrate. With use of the 2RB adaptation method tested in the present study, a reduction of feed intake at this step could be minimized through a more gradual increase in concentrate compared to the STEP adaptation method. Although the amount of roughage may not be reduced in comparison to STEP methods of adaptation (Burken, 2010), the 2RB method allows a better transition during the end of the adaptation period when higher levels of concentrate are fed.

Carcass characteristics

Krehbiel et al. (2007) stated that future coordination of the beef industry will call for improved understanding of how factors of management and nutrition affect carcass value. In the present study, management method of adaptation had a detrimental effect on marbling scores of steers adapted to the finishing diet using the 2RB method. Similar results were found in a study by Burken et al. (2010) where marbling scores of heifers adapted to the finishing diet using a similar STEP method had improved marbling scores compared to those adapted using the 2RB method.

In a comparison of restricted and ad libitum dietary adaptation, Choat et al. (2002) reported that HCW decreased due to a decrease in final live weight by steers fed a restricted diet during adaptation compared to calves fed ad libitum. However, there were no other differences in carcass characteristics of calves or yearling steers in the study.

In the past, research evidence has shown inconsistent results in the effect of by-product feeds on carcass quality. Some research supports an increase in quality grade as inclusion of WDGS increases to 40% (Larson et al., 1993; Lodge et al., 1997a); however, others show little effect at 40% inclusion (Larson et al., 1993; Koger et al., 2010). Research by Depenbusch et al. (2008) indicated that increased by-product inclusion above 25% was detrimental to quality grade. Many of these results are based on inclusion level and for most positive effect on carcass characteristics, researchers recommend distillers grains make up approximately 15 to 20% of finishing diets (Vasconcelos and Galyean, 2007; Depenbusch et al., 2008; Leibovich et al., 2009; Koger et al., 2010).

The plane of nutrition prior to entering the finishing phase has little to do with protein deposition, but can have an effect on fat deposition (Fox et al., 1972; Klopfenstein, 1999). When cattle are fed to a similar back fat endpoint, differences in marbling scores have not been observed. However, when a similar compositional endpoint is not achieved for a specific group of cattle, marbling score may show an effect of nutritional plane experienced before entering the finishing period (Klopfenstein, 1999). Although these studies focus on back grounding programs, the research does give insight into the effects of nutritional management prior to the finishing phase of the feedlot, specifically during adaptation. In the present study, differences observed in marbling due to adaptation method may be due to a similar compositional endpoint not being met for all groups of cattle. Higher marbling scores may have been achieved by steers adapted using the STEP method because they finished the adaptation period with greater BW compared to those adapted using the 2RB method. In the analysis of the entire feeding period, efficiency did not differ in steers of the different adaptation programs; however, cattle adapted using the 2RB method had numerically lower DMI throughout the entire period.

IMPLICATIONS

Data collected from this experiment provides insight into nutritional and management factors of adaptation that may not have been critically tested in the past. Results indicate that diet type has an effect on the best method of adaptation; however, sulfur levels within the DG diet played a role in decreased performance of cattle adapted using this diet. Nevertheless, analysis of the entire feeding period showed steers adapted using the DG diet recovered, performing similarly to steers adapted with the TRAD diet. Further research is needed to evaluate the efficiency of feeding procedures within the feed yard and comparative cattle performance when byproduct feeds are incorporated in adaptation diets.

LITERATURE CITED

Bartle, S. J., and R. L. Preston. 1992. Roughage level and limited maximum intake regimens for feedlot steers. J. Anim Sci. 70: 3293-3303.

Bevans, D. W., K. A. Beauchemin, K. S. Schwartzkopf-Genswein, J. J. McKinnon, and T. A. McAllister. 2005. Effect of rapid or gradual grain adaptation on subacute acidosis and feed intake by feedlot cattle. J. Anim Sci. 83: 1116-1132.

Brown, M. S., C. H. Ponce, and R. Pulikanti. 2006. Adaptation of beef cattle to high-concentrate diets: Performance and ruminal metabolism. J. Anim Sci. 84: E25-E33.

Burken, D. 2010. Evaluation of diet adaptation programs and supranutritional dietary antioxidants for feedlot cattle. M.S., Oklahoma State University.

Choat, W. T., C. R. Krehbiel, M. S. Brown, G. C. Duff, D. A. Walker, and D. R. Gill. 2002. Effects of restricted versus conventional dietary adaptation on feedlot performance, carcass characteristics, site and extent of digestion, digesta kinetics, and ruminal metabolism. J. Anim Sci. 80: 2726-2739.

Depenbusch, B. E., J. S. Drouillard, E. R. Loe, J. J. Higgins, M. E. Corrigan, and M. J. Quinn. 2008. Efficacy of monensin and tylosin in finishing diets based on steam-flaked corn with and without corn wet distillers grains with solubles. J. Anim Sci. 86: 2270-2276.

Fox, D. G., R. R. Johnson, R. L. Preston, T. R. Dockerty, and E. W. Klosterman. 1972. Protein and Energy Utilization during Compensatory Growth in Beef Cattle. J. Anim Sci. 34: 310-318.

Fulton, W. R., T. J. Klopfenstein, and R. A. Britton. 1979. Adaptation to High Concentrate Diets by Beef Cattle. I. Adaptation to Corn and Wheat Diets. J. Anim Sci. 49: 775-784.

Holland, B. P., C.R. Krehbiel, D.L. Step, L.O. Burciaga-Robles, J.J. Cranston, and L. Carlos-Valdez. 2007. Growth Perfomance and Health of Steer Calves Adapted to a High-Concentrate, Program-Fed Diet using Four Methods. Oklahoma State University.

IBC. 2008. Distiller's Grains for Beef Cows Ethanol Coproducts for Cattle. Iowa State University University Extension.

Klopfenstein, T., R. ooper, D. J. Jordon, D. shain, T. Milton, C. Calkins, and C. Rossi. 1999. Effects of backgrounding and growing programs on beef carcass quality and yield.

Klopfenstein, T. J., G. E. Erickson, and V. R. Bremer. 2008. BOARD-INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. J. Anim Sci. 86: 1223-1231.

Koger, T. J., D. M. Wulf, A. D. Weaver, C. L. Wright, K. E. Tjardes, K. S. Mateo, T. E. Engle, R. J. Maddock, and A. J. Smart. 2010. Influence of feeding various quantities of wet and dry distillers grains to finishing steers on carcass characteristics, meat quality, retail-case life of ground beef, and fatty acid profile of longissimus muscle. J. Anim Sci. 88: 3399-3408.

Krehbiel, C. R., B. P. Holland, and C. T. Milton. 2006. Grain processing effects on management: adaptation diets. In: Proc. of the Oklahoma State University Cattle Grain Processing Symp., Tulsa, Oklahoma. p pp. 156-166.

Larson, E. M., R. A. Stock, T. J. Klopfenstein, M. H. Sindt, and R. P. Huffman. 1993. Feeding value of wet distillers byproducts for finishing ruminants. J. Anim Sci. 71: 2228-2236.

Leibovich, J., J. T. Vasconcelos, and M. L. Galyean. 2009. Effects of corn processing method in diets containing sorghum wet distillers grain plus solubles on performance and carcass characteristics of finishing beef cattle and on in vitro fermentation of diets. J. Anim Sci. 87: 2124-2132.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997. Evaluation of corn and sorghum distillers byproducts. J. Anim Sci. 75: 37-43.

NRC. 1980. Mineral Tolerance of Domestic Animals. National Academy of Sciences, Washington D.C.

NRC. 2000. Minerals 7th ed. ed. Natl. Acad. Press, Washington, DC.

Pritchard, R. H., and K. W. Bruns. 2003. Controlling variation in feed intake through bunk management. J. Anim Sci. 81: E133-E138.

Rolfe, K. M., G. E. Erickson, T. J. Klopfenstein, J. T. Vasconcelos. 2010. Effects of Using Wet Distillers Grains with Solubles to Adapt Cattle to Finishing Diets on Feed Intake, Ruminal pH, and Ruminal Hydrogen Sulfide Concentration, University of Nebraska, Lincoln, NE.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, D. J. Gibb, D. H. Crews, Jr., D. D. Hickman, M. Streeter, and T. A. McAllister. 2003. Effect of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review. J. Anim Sci. 81: E149-158.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, T. A. McAllister, D. J. Gibb, M. Streeter, and A. D. Kennedy. 2004. Effect of feed delivery fluctuations and feeding time on ruminal acidosis, growth performance, and feeding behavior of feedlot cattle. J. Anim Sci. 82: 3357-3365.

Vasconcelos, J. T., and M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim Sci. 85: 2772-2781.

Table 3.1. Diet ingredient and nutrient composition.

Item[2]	Diet % Concentrate						
	DG Adaptation Diets[4]			TRAD Adaptation Diets[5]			Finisher
Adaptation Diet Steps	DG1	DG2	DG3	TRAD1	TRAD2	TRAD3	Finisher
Dry rolled corn		36.0	18.0	34.71	41.14	47.57	54.00
Corn WDGS	84.0	48.0	66.0	19.29	22.86	26.43	30.00
Ground alfalfa hay				20.00	13.33	6.67	10.00
Ground grass hay	10.0	10.0	10.0	20.0	16.67	13.33	
B-252 Supplement[1]	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Nutrient Composition[3]							
DM, %	39.12	43.05	51.40	65.43	63.50	64.94	59.56
$NE_{m,}$ Mcal/kg	1.90	1.98	1.94	1.71	1.81	1.91	2.02
$NE_{g,}$ Mcal/kg	1.20	1.21	1.23	1.04	1.12	1.21	1.29
CP, %	26.64	18.93	22.79	13.72	14.17	14.62	15.08
ADF, %	18.14	13.55	15.85	20.68	17.54	14.39	11.25
NDF, %	25.82	21.12	23.47	30.37	26.51	22.64	18.77
Ca, %	0.88	0.81	0.84	1.09	0.98	0.88	0.77
P, %	0.69	0.51	0.60	0.36	0.38	0.40	0.43

[1] Formulated to contain the following ingredients (DM basis): 43.11% ground corn, 16.67% wheat midds, 5.0% KCL, 27.5% limestone, 4.17% salt, 0.03% MnO, 0.25% $ZnSO_4$, 1.67% MgO, 0.06% Vitamin-A (30,000 IU/g), 0.04% Vitamin E (50%), 1.0% Thiamine 10, 0.31% Rumensin 80, 0.19%
Tylan 40.

[2]All values except DM are expressed on a 100% DM basis.

[3]Actual values are shown.

[4] Wet distillers grains with solubles adaptation diets (DG) 1, 2, and 3 each contain 90% concentrate.

[5] Traditional adaptation diets (TRAD) 1, 2, and 3 contain 60, 70, and 80% concentrate, respectively.

Table 3.2. Adaptation scheme for TRAD and DG diets using 2RB and STEP adaptation methods.

	2RB Adaptation Method		STEP Adaptation Method			
	AM Call	PM Call	AM Call	PM Call	AM Call	PM Call
Day	% DG1 or TRAD1	% of Finisher[3]	TRAD Diet[1]	TRAD Diet[1]	DG Diet[2]	DG Diet[2]
1	95.45%	4.55%	1	1	1	1
2	90.91%	9.09%	1	1	1	1
3	86.36%	13.64%	1	1	1	1
4	81.82%	18.18%	1	1	1	1
5	77.27%	22.73%	1	1	1	1
6	72.73%	27.27%	1	1	1	1
7	68.18%	31.82%	1	2	1	2
8	63.64%	36.36%	1	2	1	2
9	59.09%	40.91%	2	2	2	2
10	54.55%	45.45%	2	2	2	2
11	50.00%	50.00%	2	2	2	2
12	45.45%	54.55%	2	2	2	2
13	40.91%	59.09%	2	2	2	2
14	36.36%	63.64%	2	3	2	3
15	31.82%	68.18%	2	3	2	3
16	27.27%	72.73%	3	3	3	3
17	22.73%	77.27%	3	3	3	3
18	18.18%	81.82%	3	3	3	3
19	13.64%	86.36%	3	3	3	3
20	9.09%	90.91%	3	3	3	3
21	4.55%	95.45%	3	Finisher[3]	3	Finisher[3]
22	-	100.00%	3	Finisher[3]	3	Finisher[3]
23-28	-	100.00%	Finisher[3]	Finisher[3]	Finisher[3]	Finisher[3]
29-End	-	100.00%	Finisher[3]	Finisher[3]	Finisher[3]	Finisher[3]

[1]TRAD adaptation diets 1, 2, and 3.
[2]DG adaptation diets 1, 2, and 3.
[3]The finishing diet.

Table 3.3. Effect of adaptation programs on finishing cattle performance.

	Adaptation Program[1]							
	TRAD Diet		DG Diet			*P* - value		
Item	STEP	2RB	STEP	2RB	SEM[2]	D	M	D×M
No. of steers	32	33	35	34				
No. of pens	6	6	6	6				
BW, kg								
d 0	358.1	357.8	354.6	357.5	32.0	0.88	0.20	0.79
d 28	381.9	381.0	361.0	361.5	35.2	< 0.01	0.96	0.86
d 56	424.3	438.3	417.0	415.3	37.1	< 0.01	0.17	0.08
d 84	457.9	478.7	458.2	460.6	36.4	0.12	0.04	0.10
Final	611.7	629.7	613.6	600.7	22.2	0.05	0.70	0.03
Carcass Adj.[3]	616.6	619.0	610.8	617.3	22.2	0.66	0.60	0.81
DMI kg/d								
d 0 to 28	7.40	7.54	4.63	4.63	0.71	< 0.01	0.82	0.84
d 29 to 56	8.51	9.79	8.54	8.48	0.89	0.12	0.13	0.10
d 57 to 84	9.37	10.44	9.69	9.82	0.94	0.66	0.08	0.17
d 84 to end	11.36	11.33	11.54	10.94	0.55	0.71	0.29	0.33
d 0 to end	9.82	10.31	9.41	9.21	0.58	0.01	0.59	0.23
ADG, kg/d								
d 0 to 28	1.01	0.83	0.23	0.14	0.17	< 0.01	0.24	0.65
d 29 to 56	1.51	2.00	2.05	1.92	0.15	0.19	0.10	0.03
d 57 to 84	1.20	1.43	1.47	1.62	0.18	0.22	0.29	0.80
d 84 to end	2.19	2.10	2.22	1.91	0.13	0.33	0.02	0.20
d 0 to end	1.65	1.73	1.66	1.55	0.05	0.03	0.69	0.01
Carcass Adj.[3]	1.67	1.66	1.64	1.65	0.06	0.75	0.99	0.80
G:F, kg:kg								
d 0 to 28	0.14	0.03	0.09	0.03	0.02	< 0.01	0.31	0.34
d 29 to 56	0.18	0.24	0.22	0.23	0.02	0.05	0.35	0.12
d 57 to 84	0.13	0.16	0.14	0.17	0.03	0.23	0.47	0.95
d 84 to end	0.19	0.19	0.18	0.18	0.01	0.38	0.05	0.45
d 0 to end	0.17	0.18	0.16	0.18	0.01	0.34	0.51	0.36
Carcass Adj.[3]	0.17	0.16	0.17	0.18	0.01	0.10	0.86	0.26

[1]Adaptation Program = Traditional (TRAD) diet or Wet distillers grains with solubles (DG) diet using step-up method (STEP) and two-ration blending method (2RB).

[2]Standard error of the least squared means.

[3]Calculated using carcass adjusted BW as HCW/average dressing percentage of all harvest blocks.

Table 3.4. Effect of finishing diet adaptation method on daily bunk sample nutrient composition during adaptation period (d 0 to 28).[3]

	Adaptation Program[1]							
	TRAD Diet				DG Diet			
Item[3]	STEP	SD[2]	2RB	SD[2]	STEP	SD[2]	2RB	SD[2]
Crude protein, %	15.94	0.79	16.08	0.65	21.32	0.42	18.35	0.80
ADF, %	15.67	1.03	12.96	0.85	15.72	0.89	13.99	0.64
NDF, %	28.74	1.88	22.98	1.21	25.38	1.72	23.85	1.52
Fat, %	4.59	0.13	5.01	0.16	6.45	0.09	5.77	0.21
NE_m, mcal/cwt	0.87	0.05	0.96	0.01	0.86	0.05	0.96	0.01
NE_g, mcal/cwt	0.57	0.04	0.66	0.01	0.57	0.04	0.65	0.00
ME, mcal/cwt	1.30	0.06	1.41	0.02	1.29	0.06	1.40	0.01
Sulfur, %	0.46	0.01	0.47	0.02	0.71	0.03	0.58	0.02

[1]Adaptation Program = Traditional (TRAD) diet or Wet distillers grains with solubles (DG) diet using step-up method (STEP) and two-ration blending method (2RB).
[2]SD = standard deviation.
[3]Analyzed values: (ServiTech Laboratories, Dodge City, KS)

Table 3.5. Effect of finishing diet adaptation diet on carcass traits and distribution of USDA Quality and Yield Grades and calculated quality and yield grades.

	Adaptation Diet[1]			*P* - value
Item	TRAD	DG	SEM[2]	Diet
No. of steers	65	69		
No. of pens	12	12		
HCW, kg	875.50	870.17	30.24	0.65
Dressing %	64.14	64.54	0.46	0.43
LM area, cm^2	14.25	14.08	0.26	0.37
12^{th} rib fat, cm	0.37	0.40	0.02	0.30
KPH %	1.82	1.72	0.05	0.11
Marbling[3]	335.33	324.17	15.46	0.31
Calculated YG	2.50	2.62	0.11	0.27
USDA Quality Grade[4]				
Prime	-	-	-	-
Choice	34.1	28.5	0.51	0.52
Select	61.9	64.1	0.58	0.80
No Roll	2.8	5.5	0.77	0.43
Quality Grade[3]				
$Choice^{+}$	-	-	-	-
$Choice^{o}$	-	-	-	-
$Choice^{-}$	29.4	26.4	0.44	0.71
Select	61.9	64.1	0.44	0.80
No Roll	2.8	5.5	0.76	0.43
USDA Yield Grade[4]				
1	20.5	21.5	0.36	0.88
2	49.6	46.2	0.25	0.77
3	24.5	27.3	0.40	0.70
4, 5	3.0	2.9	0.73	0.97
Calc. Yield Grade				
≥ 1.99	11.9	10.7	0.69	0.80
2.0 – 2.49	11.0	6.1	0.81	0.27
2.5 – 2.99	64.9	68.3	1.21	0.75
3.0 – 3.49	8.4	11.1	0.72	0.57
3.5 – 3.99	1.8	1.9	1.21	0.96
4.0 – 4.49	1.5	1.4	1.0	0.97
4.5 – 4.99	-	-	-	-
$5.0 \leq$	-	-	-	-

[1]Adaptation Diet = Traditional (TRAD) diet or
Wet distillers grains with solubles (DG) diet.
[2]Standard error of the least squared means. Largest standard error shown.
[3]Quality grade based on marbling score. Marbling score units:
300 = Sight00, 400 = Small00, 500 = Modest00.
[4]Data collected from USDA grader at commercial abattoir called at chain speed.

Table 3.6. Effect of finishing diet adaptation method on carcass traits and distribution of USDA Quality and Yield Grades and calculated quality and yield grades.

	Adaptation Method[1]			*P* - value
Item	STEP	2RB	SEM[2]	Method
No. of steers	67	67		
No. of pens	12	12		
HCW, kg	869.67	876.00	30.24	0.59
Dressing %	64.50	64.18	0.46	0.52
LM area, cm^2	14.13	14.21	0.26	0.68
12^{th} rib fat, cm	0.40	0.37	0.02	0.38
KPH %	1.78	1.76	0.05	0.66
Marbling[3]	341.17	318.33	15.46	0.04
Calculated YG	2.60	2.51	0.11	0.42
USDA Quality Grade[4]				
Prime	-	-	-	-
Choice	37.0	26.0	0.51	0.21
Select	59.3	66.6	0.58	0.41
No Roll	2.8	5.5	0.77	0.44
Quality Grade[3]				
$Choice^{+}$	-	-	-	-
$Choice^{o}$	-	-	-	-
$Choice^{-}$	28.6	27.2	0.44	0.86
Select	59.3	66.6	0.44	0.41
No Roll	2.8	5.5	0.76	0.44
USDA Yield Grade[4]				
1	15.5	27.9	0.36	0.09
2	56.3	39.7	0.25	0.30
3	23.6	28.3	0.40	0.54
4, 5	3.1	2.9	0.73	0.94
Calc. Yield Grade				
≤ 1.99	6.1	20.0	0.69	0.01
2.0 – 2.49	9.2	7.3	0.81	0.65
2.5 – 2.99	76.9	54.4	1.21	0.03
3.0 – 3.49	8.3	11.3	0.72	0.52
3.5 – 3.99	1.1	3.2	1.21	0.35
4.0 – 4.49	1.5	1.4	1.0	0.96
4.5 – 4.99	-	-	-	-
$5.0 \leq$	-	-	-	-

[1]Adaptation Method = Step-up (STEP) or two-ration blend (2RB) adaptation methods.
[2]Standard error of the least squared means. Largest standard error shown.
[3]Quality grade based on marbling score. Marbling score units: 300 = Sight00, 400 = Small00, 500 = Modest00.
[4]Data collected from USDA grader at commercial abattoir called at chain speed.

CHAPTER IV

ACIDOSIS CHALLENGE EFFECTS ON RUMINAL PH AND TEMPERATURE IN BEEF CATTLE

ABSTRACT: Twelve ruminally cannulated steers with ruminal pH and temperature monitoring devices were used to determine the effects of an acidosis challenge on ruminal pH and temperature. Steers were offered the control diet at 2% BW/d prior to the challenge and starting 24 h after the challenge. Challenges were ruminal dosing of 2% BW of 65% concentrate diet (CON), a mixture of 50:50 dry rolled corn: wet distillers grains (DG/DRC), or 100% dry rolled corn (DRC) at 0 h. Bolus readings for ruminal pH (RpH) and ruminal temperature (RT) were recorded every minute for 72 h after dosing and compiled in 3 h increments for repeated measures analysis. Rumen pH was taken manually every 3 h for 72 h after dosing and analyzed with a repeated measures analysis. During the challenge period, DMI of treatments were not statistically different. There were significant interactions of treatment × h ($P = 0.05$), treatment × day ($P = 0.02$) and d × h ($P = 0.03$) for RpH. Dosing of challenge treatment and normal feeding on subsequent days of the challenge period caused RpH to move in a diurnal fashion, illustrated by RpH decreasing consistently 9 h following a meal each day. Dosing of challenge treatments on d 1 caused DG/DRC steers to have lower ($P = 0.01$) RpH than CON steers; DRC steers being intermediate. On d 2, DG/DRC steers had lower ($P = 0.01$) RpH than CON steers. No differ-

ence in RpH was observed for treatments on d 3 ($P \leq 0.80$). Main effects of treatment and d were not significant ($P \leq 0.48$) for RT, however, there was a quadratic response ($P < 0.01$) h 9 through 21, h 15 (39.64°C) having greater RT ($P < 0.01$) compared to h 0. These results indicate that increased availability of highly fermentable substrates in the rumen result in decreases in RpH and increases in RT. However, the type of fermentable substrate may change the relationship between rumen temperature and pH, particularly when substrates such as distiller's grains that have a low pH are included in the diet.

INTRODUCTION

Highly fermentable carbohydrates provide energy in finishing diets to allow increased feedlot efficiency. Although dry rolled corn (DRC) has been traditionally used as a concentrate source, by-products from ethanol production have provided alternate sources of protein and energy in feedlot finishing diets. Results of research indicate increased beef cattle performance when distillers grains are incorporated in feedlot diets with traditional feed sources such as DRC (Larson et al., 1993; Ham et al., 1994; Al-Suwaiegh et al., 2002), high moisture corn (HMC) and steam flaked corn (SFC) (Corrigan, 2007) as compared to those traditional feed sources fed alone. However, there has been little controlled research directed to evaluate the metabolic effect of distiller's grains when compared to traditional concentrate sources.

Schwartzkopf-Genswein et al. (2003) conveyed that animals distinctly vary in their ability to cope with dietary factors that predispose them to acidosis. Improved technology has provided options to more closely monitor metabolic activity and animal variation, specifically providing a more detailed picture in instances of digestive upset that would go unnoticed in a classical feedlot setting (Cooper, 1998). Dietary treatments utilized in this trial were designed to test the effectiveness of ruminal monitoring devices and determine if there is a relationship between ruminal pH and temperature in an acidosis situation.

MATERIALS AND METHODS

Animals

All procedures were approved by the Oklahoma State University Animal Care and Use Committee. Twelve steers were utilized for a metabolism study to evaluate the effects of an acidosis challenge on ruminal pH (RpH) and ruminal temperature (RT) levels using two RpH and RT monitoring devices. Steers were previously equipped with ruminal cannulas and allotted by weight using a complete randomized block design. Steers were fed a 65% concentrate diet fed for 30 d prior to challenge. The diet supplied monensin (Elanco Animal Health, Greenfield, IN) and tylosin (Elanco Animal Health, Greenfield, IN) at 35.2 and 10.5 mg/kg (90% DM basis), respectively. The diet was offered at 2% BW (DM basis). Steers were housed indoors in 2.4 x 3.8 m individual stalls with ambient temperature control. Water was available ad libitum via automatic water units located in each stall (Table 4.1).

Experiment

Steers were assigned randomly to one of three challenge treatments (Table 4.1); 1) (CON), no dietary change; 2) (DRC), 100% daily intake replaced with dry rolled corn; 3) (DG/DRC), 50:50 ratio of wet distillers grains with solubles to dry rolled corn. All treatments were provided the CON diet prior to the challenge period and on d 2 and 3 of the challenge period.

The 16 d experimental period was divided into three phases: pre-challenge, challenge, and post-challenge. Days -2 through 0 were the pre-challenge phase in which steers were fed CON at 0800 at a level of 2% BW each day. Pre-challenge data was averaged for all animals in each treatment and was considered the h 0 measurement of the challenge period for each respective treatment. The challenge period began at 0800 on d 1 when steers were dosed with respective challenge treatments through the rumen cannula at 2% BW, no additional diet being fed that day. In order to minimize differences due to hydration, water was added to CON and

DRC 1 h before dosing according to the DM of DG/DRC. Immediately prior to dosing at 0800, ruminal fluid was sampled through the rumen cannula to measure initial RpH. Ruminal fluid was obtained by suction through vinyl tubing equipped with a strainer (Raun and Burroughs, 1962) through small incisions in the cannula caps. Immediately after sampling, each sample was evaluated for RpH using a combination electrode. Immediately following, 30 liters of ruminal contents were removed from each steer and followed by subsequent dosing of the respective challenge treatments intraruminally. Normal feeding of the CON diet resumed at 0800 of d 2 and 3 and after the challenge period for all steers and continuing until the end of the entire experiment period. Orts were collected each day before feeding, weighed, and subsampled for DM determination.

Ruminal monitoring of pH and temperature was conducted by KB1000 series boluses (Kahne Limited, Aukland, New Zealand) beginning in the pre-challenge period. Two days prior to the challenge, the boluses were calibrated and inserted through the rumen cannula to float freely just below the fiber mat. The boluses continuously transmitted RpH and RT readings every minute through the KR2001 transceiver (Kahne Limited, Aukland, New Zealand) into the Kahne software program during the 16 d experiment period in addition to also recording the data directly on the bolus. Data recorded on the KB1000 bolus was later downloaded and used for ruminal pH and temperature analysis.

Individual steer temperatures associated with water drinking events were identified and removed from the data set. The beginning of a drink event was identified by a ruminal temperature decrease of at least 0.40°C from the previous measurement. The conclusion of a drinking event was identified when ruminal temperature either ceased to increase, or increased to the last temperature observed prior to the drinking event.

Statistical analysis

For all statistical analyses, steer was the experimental unit and random effects included challenge; steer within challenge and treatment × id within challenge. Response variables included RpH, fluid pH, RT, amount of time spent below acidosis threshold ruminal pH 5.6 and 5.2, and amount of time spent above RT 39.0°C and 39.45°C. The change from one given sampling time to the next was calculated to find amount of time under RpH thresholds and time above RT thresholds. The time below RpH and time above RT thresholds was summarized by day prior to analysis.

Measurements of RpH and RT were averaged in 30 minute intervals and analyzed using the GLIMMIX procedure of SAS (SAS Institute Inc. Cary, NC) with each 30 minute interval serving as a repeated measure. Least squares means were calculated and considered significant when $P \leq 0.05$. Mean differences are discussed when $P \leq 0.05$ and considered tendencies when $0.05 < P \leq 0.10$.

The CORR procedure of SAS (SAS Institute Inc. Cary, NC) was utilized to determine correlation relationships of bolus RpH vs. RT and bolus RpH vs. fluid pH by day. The CORR procedure of SAS was also utilized for the amount of time spent above RT 39°C, the amount of time spent above RT 39.45°C, the amount of time spent below a bolus RpH of 5.2, and the amount of time spent below a bolus RpH of 5.6 within each treatment according to methodology by Cooper et al. (1999). Regression analysis of SAS (SAS Institute Inc. Cary, NC) was used to determine correlations between response variables of bolus RpH, fluid RpH, and RT. PROC REG (SAS Institute Inc. Cary, NC) was utilized specifically to determine the relationships of bolus pH vs. fluid pH.

RESULTS

Dry matter intakes of treatments were not statistically different ($P = 0.34$) during the 16 d experimental period. Ruminal fluid pH was sampled through the rumen cannula in 3 h

increments for 72 h during the challenge period and was used as a method of validation for bolus pH measurements (Table 4.2). Strong correlations between bolus pH measurements and fluid pH measurements give reason to present only ruminal pH data taken from the bolus. Through the analysis of bolus RpH vs. fluid RpH, the R^2 was 0.60. Due to the R^2 value of bolus pH vs. fluid pH, the bolus pH measurements will be presented as the primary measure of RpH.

Measurements of RpH during the experiment are shown in Figure 4.1. There was a treatment × h interaction ($P = 0.05$) for RpH. On h 0, RpH for DRC and DG/DRC steers were 0.65 and 0.46 units lower ($P \leq 0.05$) than CON (pH 6.33) steers at pH 5.68 and 5.87, respectively. There were no differences between steers on h 3, 6, and 9. On h 12, RpH was 5.35 being 0.50 units lower ($P = 0.03$) for DG/DRC steers compared to CON steers. There was a tendency for DG/DRC steers to be lower ($P = 0.06$) on h 15 compared to CON steers. On h 18, RpH (5.46) was 0.59 units lower ($P = 0.01$) for DG/DRC steers compared to CON steers and there was a tendency of RpH to be lower ($P = 0.09$) for DRC steers compared to the CON steers. On h 21, RpH (5.57) was 0.47 units lower ($P = 0.04$) for DG/DRC steers compared to CON steers.

There was an interaction of treatment × d ($P = 0.02$) for RpH. Dosing of challenge treatments on d 1 caused DG/DRC steers to have RpH of 5.24 being 0.60 units lower ($P = 0.01$) than CON steers. On d 2, RpH of DG/DRC steers were 0.49 units lower ($P = 0.01$) than CON steers at a pH level of 5.37; however, DRC steers tended ($P = 0.06$) to be higher than CON steers. There was no difference in RpH for treatments on d 3 ($P \leq 0.80$).

Ruminal pH also detected a day × h interaction ($P = 0.03$). On h 0 of d 2, RpH was 0.53 units lower ($P < .01$) than d 1 at pH 5.67 increasing ($P = .01$) 0.34 units on d 3. Compared to d 1, RpH decreased ($P = 0.02$) on h 3 of d 2, to pH 5.45. On d 3, RpH increased ($P = 0.01$) to 5.70 from RpH on d 2. On h 6 of d 3 RpH rose 0.39 units to pH 5.66 ($P = 0.01$) compared to d 1. Ruminal pH on h 6 of d 3 tended ($P = 0.09$) to be greater than h 6 of d 2. Ruminal pH was 5.58 at h 9 of d 3 being 0.33 and .31 units greater ($P \leq 0.02$) than d 1 and d 2. On h 12 of d 3, RpH 5.63

was 0.33 units greater ($P = 0.02$) than d 1. There was a tendency ($P = 0.09$) for h 12 of d 3 to have a greater RpH than h 12 of d 2. On h 15 of d 3, RpH was 5.73 being 0.31 and 0.14 units greater ($P \leq .03$) than d 1 and d 2. Compared to h 18 on d 1, RpH increased 0.51 units to 5.98 on d 3, indicating a recovery of RpH over the challenge period. At h 21 of d 2 and 3, RpH was 0.31 and 0.50 units greater ($P \leq 0.03$) than RpH on d 1 (5.53). The interaction of treatment × d × h was not significant ($P = 0.15$).

Measurements of RT during the experiment are shown in Figure 4.2. After challenge, the main effects of treatment and d were not significant for RT; however, RT did indicate an h effect ($P < 0.01$). There was a quadratic response for RT ($P < 0.01$) h 9 through 21, h 15 (39.64°C) being greatest ($P < 0.01$) compared to h 0. A similar quadratic ($P < 0.01$) response was observed for RT on h 9, 12, 15, 18, and 21 being 0.35, 0.39, 0.51, 0.39 and 0.31°C units greater ($P < 0.01$) than h 3 (39.31°C). When compared to h 6 (39.25°), RT on h 9, 12, 15, and 18 was 0.23, 0.27, 0.39, 0.27°C unit's greater ($P \leq 0.01$). There was a tendency for RT to be greater ($P = 0.08$) on h 21 when compared to h 6.

Correlations between response variables of RpH and RT are shown in Table 4.2. For CON steers RpH was correlated ($P < 0.01$) to RT on all d, significant correlations ranging from -0.56 to -0.79. On d 1, RpH for DRC steers was not correlated (P = 0.56); however, RpH of DG/DRC steers was correlated ($P < 0.01$, r = -0.60) with RT. On d 2 similar results were observed; DRC having no correlation (P =0.45) of RpH and RT where RpH of DG/DRC steers was correlated ($P < 0.01$, r = 0.53) to RT. On d 3, RpH for DRC steers was correlated ($P < 0.01$, r = -0.59) to RT but no correlation ($P = 0.13$) was detected for DG/DRC steers on d 3.

Results of time spent below RpH of 5.2 and 5.6 and above RT of 39.0°C and 39.45°C are shown in Table 4.4. Data collected for RpH and RT are summarized in a similar format, utilizing amount of time above or below a given threshold to identify severity of acidosis. Treatment

means are listed for each treatment according to each of the threshold levels. Due to time gaps of the data recorded by the bolus, individual responses to the treatments were not a true representation of the individual time means. For this reason, only treatment means are listed in Table 4.4.

DISCUSSION

According to Owens et al. (1998), acidosis encompasses the buildup of organic acids (VFA and lactic acid) causing a decrease in RpH. The variation of response in rumen environments due to low ruminal pH have led to the used of different thresholds for acidosis classification; Owens et al. (1998) defined subacute ruminal acidosis as a RpH of 5.0 to 5.6 where RpH less than 5.0 is considered acute ruminal acidosis. Krause and Oetzel (2005) designated a threshold of ≤ 5.6 to indicate subacute ruminal acidosis. In an acidosis study using Holstein cows, Penner et al. (2007) defined acute acidosis as a RpH $\leq$ pH 5.2. According to various research reports, the present study utilized a threshold ≤ 5.6 as subacute ruminal acidosis and a threshold ≤ 5.2 as ruminal acute acidosis.

During the present study, subacute ruminal acidosis levels were attained; all cattle reached a RpH below acidosis threshold of 5.6. The DG/DRC steers reached levels below the threshold of acute acidosis shortly following dosing of the challenge treatments on d 1 most likely due to WDGS having a pH less than 4.0 (IBC, 2008). On d 1, RpH for DRC steers was reduced to nadir RpH 5.18, remained low on d 2 (5.17) before increasing on d 3 (5.54). The reduction of RpH for DRC steers occurred due to a high amount of starch having a greater effect on the duration and severity of decreased RpH. Parallel to research done by Krause et al. (2005), RpH for DRC and DG/DRC steers on d 2 and d 3 were below initial values but recovered in subsequent days (see Figure 1) following dosing of the challenge treatments on d 1.

Dohme et al (2008) induced ruminal acidosis in dairy cows in different stages of lactation by offering a 100% concentrate diet after a period of dietary restriction. Within 1 d following induction of acidosis, RpH in high risk cows was reduced 0.32 units to mean and minimum ruminal pH of 5.56 and 4.89, respectively. Also, high risk acidotic cows spent 57 minutes below a ruminal pH of 5.5. Duration and extent of response in high risk cows was comparable to response in the present experiment; however, steers in the present experiment had increased time spent below RpH thresholds. In the present experiment, mean RpH on d 1 was reduced 0.34, 0.68, and 1.07 units from initial pH for CON (5.87), DRC (5.53), and DG/DRC (5.21) steers respectively. From initial pH levels on d 1, RpH was reduced to minimum levels 0.93, 1.03, and 1.40 units from initial pH for CON (5.49), DRC (5.18), and DG/DRC (4.87) steers respectively. On d 2, RpH of CON and DRC steers decreased slightly to pH 5.44 and 5.17, DG/DRC steers increasing 0.31 units compared to d 1 nadir levels. On d 3, RpH recovered for all treatments. These results are similar to those reported by Dohme et al. (2008), but steers on all treatments in the present study reached lower RpH most likely due to the challenge diet being fed compared to intraruminally dosed at two percent body weight in present study.

Cooper et al. (2002) conducted an acidosis challenge to identify nutrient digestion and fermentation differences of different corn processing methods. After a 14-d period of adaptation, cattle fed 80% DRC to induce acidosis reached RpH nadir of pH 5.5; however, in the present challenge DRC steers reached nadir pH at 5.17. Steers in the present study were not adapted to the challenge diets and diets were intraruminally dosed at two percent body weight rather than fed, again, providing a probable explanation for the reduced RpH levels compared to research done by Cooper et al. (2002).

Diurnal variation of RpH is explained in studies where average RpH of grain-fed cattle ranged from 5.8 to 6.2 showing a drop to 5.6 or below after normal daily feeding (Schwartzkopf-Genswein et al., 2003; Nagaraja and Titgemeyer, 2007). A characteristic example of this

occurred in the present study where RpH of CON steers behaved quadratically by day, achieving maximum pH shortly before feeding and a consistent RpH minimum 9 h after feeding each day. In subsequent days following dosing of challenge treatments, RT responded quadratically 9 hours following feeding. The quadratic relationships observed by h represent diurnal variation observed by others (Bitman et al., 1984; Mader et al., 2002; Rose-Dye et al., 2011; Wahrmund, 2011) indicating it is common for ruminants to experience a daily variation of ruminal pH when high starch diets are fed. Additionally, a study by Krause and Oetzel (2005) found nadir RpH levels occurring 10 h post-feeding in the period before the challenge and 12 to 13 h post-feeding during the challenge period. The present study observed nadir RpH levels during the challenge period were similar to the pre-challenge period in the Krause and Oetzel study (2005) occurring 9 h post-feeding for all treatments on all d with exception to h 6 of d 1 (5.18) for DRC steers and on d 3 of h 12 (5.31) for DG/DRC steers.

AIZahal et al. (2008) directed a subacute acidosis challenge on dairy cows, continuously monitoring RpH and RT during adaptation and challenge periods. Ruminal pH of cows treated to achieve subacute ruminal acidosis was reduced 0.33 and 0.42 units of mean and minimum RpH, respectively compared to control cows. Also compared to control, RT of acidotic cows increased 0.67°C and 0.57°C units above mean and minimum temperatures, respectively. Cows receiving diets to induced subacute acidosis spent greater time above 39.0 and 39.2°C with correlations between RpH and RT being highest time below pH 5.6 and for time above 39.4°C. Similar results were found in the present trial where correlations between RpH and RT were highest for time spent below RpH 5.2 and 5.6 and time spent above RT 39.45°C. Specifically, time spent above RT thresholds for DRC steers overall was numerically higher than DG/DRC steers; CON steers being intermediate. Increased RT for DRC steers could be due to heat of fermentation of a treatment source high in starch content compared to other treatments. The potential for RT to predict RpH was supported by DRC steers that spent greater time above RT 39.0°C and 39.45°C

and below RpH 5.6. In the present trial, total amount of time spent above and below ruminal temperature and pH thresholds was much greater, most likely due to cattle being intraruminally dosed 100% concentrate diet at 2% BW. Amount of time spent above and below RpH and RT thresholds was greater in the present study than research results presented by Wahrumund et al. (2011), most likely due to more severe reduction in pH from the use of WDGS in the challenge diet of the present study. Mader et al. (2002) suggests high concentrate diets cause an increased metabolic heat load resulting in increased core body temperatures following feeding. Results of the current study showed similar results where cattle dosed with DRC and DG/DRC treatments had numerically greater RT than CON steers. More specifically, RT of DRC was greater than DG/DRC most likely due to a greater extent of ruminal fermentation.

Wahrmund et al. (2011) conducted an acidosis challenge on steers to test correlations between RpH and RT. Within the trial, significant correlations were produced between RpH and RT, indicating high RT may be a plausible indicator of low RpH. In the present study, RpH in DG/DRC steers exhibited a strong negative correlation with RT on d 1; however on d 2, RpH in DG/DRC steers was positively correlated ($P < 0.01$, $r = 0.53$) to RT, indicating an extreme initial drop in ruminal pH on d 1 due to low pH of a by-product feed such as WDGS. Comparable results with the present study are achieved by AlZahal et al. (2007) who indicated a negative relationship between RpH and RT, providing potential for RT to predict RpH.

Steers dosed with CON experienced RpH (5.44) at its lowest point h 9 of d 2 and the highest observed RT (39.77°C) occurred on h 15 of d 3. However, nadir of RpH (4.87) for the DG/DRC steers occurred at h 6 of d 1 followed by the occurrence of the highest RT (39.72°C) 6 h later. Steers on DRC treatment experienced lowest RpH (5.17) for DRC steers on h 9 of d 2 followed by their highest RT (40.03°C) 9 h later. Low RpH did not coincide with high RT in CON steers; however similarities occurred between DG/DRC and DRC steers. Although occurrence differed by d, lowest RpH followed highest ruminal temperature by 6 and 9 h for

DG/DRC and DRC steers, respectively. This association agrees with AlZahal et al. (2008 and 2009) where accelerated ruminal fermentation following grain feeding was linked to a reduction in RpH and an elevation in RT.

IMPLICATIONS

Results of this trial show that feed type affects RpH which is illustrated by DG/DRC steers having a lower RpH compared to DRC and CON steers. Through use of ruminal monitoring devices, it was evident that acidosis affects RT; however the extent of effect depends on feed type demonstrated specifically by DRC steers having a higher RT than DG/DRC or CON steers. Results from this trial indicate that RT may be a good indicator of RpH when a highly fermentable diet is fed; however RT indicators of RpH may be increasingly valuable if further research determines the specific relationship of fermentation to RpH and acidosis. Under field conditions, ruminal monitoring devices allow observations to be made over longer periods of time, something not easily accomplished with a manual sampling; however factors such as heat stress and estrus need to be ruled out in order for ruminal temperature data to be accurately quantified.

LITERATURE CITED

Ahrens, F. A. 1967. Histamine, Lactic Acid and Hypertonicity as factors in the Development of Rumenitis. Am. J. Vet. Res. 28: 1335.

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002. Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim Sci. 80: 1105-1111.

AlZahal, O., E. Kebreab, J. France, M. Froetschel, and B. W. McBride. 2008. Ruminal Temperature May Aid in the Detection of Subacute Ruminal Acidosis. J. Dairy Sci. 91: 202-207.

AlZahal, O., M. A. Steele, E. V. Valdes, and B. W. McBride. 2009. Technical note: The use of a telemetric system to continuously monitor ruminal temperature and to predict ruminal pH in cattle. J. Dairy Sci. 92: 5697-5701.

Bartle, S. J., and R. L. Preston. 1992. Roughage level and limited maximum intake regimens for feedlot steers. J. Anim Sci. 70: 3293-3303.

Bauer, M. L., D. W. Herold, R. A. Britton, R. A. Stock, T. J. Klopfenstein, and D. A. Yates. 1995. Efficacy of laidlomycin propionate to reduce ruminal acidosis in cattle. J. Anim Sci. 73: 3445-3454.

Beharka, A. A., T. G. Nagaraja, J. L. Morrill, G. A. Kennedy, and R. D. Klemm. 1998. Effects of Form of the Diet on Anatomical, Microbial, and Fermentative Development of the Rumen of Neonatal Calves. J. Dairy Sci. 81: 1946-1955.

Bergen, W. G., and D. B. Bates. 1984. Ionophores: Their Effect on Production Efficiency and Mode of Action. J. Anim Sci. 58: 1465-1483.

Bergman, E. N. 1990. Energy contributions of volatile fatty acids from the gastrointestinal tract in various species. Physiol. Rev. 70: 567-590.

Bevans, D. W., K. A. Beauchemin, K. S. Schwartzkopf-Genswein, J. J. McKinnon, and T. A. McAllister. 2005a. Effect of rapid or gradual grain adaptation on subacute acidosis and feed intake by feedlot cattle. J. Anim Sci. 83: 1116-1132.

Bevans, D. W., K. A. Beauchemin, K. S. Schwartzkopf-Genswein, J. J. McKinnon, and T. A. McAllister. 2005b. Effect of rapid or gradual grain adaptation on subacute acidosis and feed intake by feedlot cattle. J. Anim Sci. 83: 1116-1132.

Bitman, J., A. Lefcourt, D. L. Wood, and B. Stroud. 1984. Circadian and Ultradian Temperature Rhythms of Lactating Dairy Cows. J. Dairy Sci. 67: 1014-1023.

Brown, H., R. F. Bing, H. P. Grueter, J. W. McAskill, C. O. Cooley, and R. P. Rathmacher. 1975. Tylosin and Chlortetracycline for the Prevention of Liver Abscesses, Improved Weight Gains and Feed Efficiency in Feedlot Cattle. J. Anim Sci. 40: 207-213.

Brown, M. S., C. R. Krehbiel, M. L. Galyean, M. D. Remmenga, J. P. Peters, B. Hibbard, J. Robinson, and W. M. Moseley. 2000. Evaluation of models of acute and subacute acidosis on dry matter intake, ruminal fermentation, blood chemistry, and endocrine profiles of beef steers. J. Anim Sci. 78: 3155-3168.

Brown, M. S., C. H. Ponce, and R. Pulikanti. 2006. Adaptation of beef cattle to high-concentrate diets: Performance and ruminal metabolism. J. Anim Sci. 84: E25-E33.

Burken, D. 2010. Evaluation of diet adaptation programs and supranutritional dietary antioxidants for feedlot cattle. M.S., Oklahoma State University.

Burrin, D. G., and R. A. Britton. 1986. Response to Monensin in Cattle during Subacute Acidosis. J. Anim Sci. 63: 888-893.

Byers, F. M., G.T. Schelling. 1993. The Ruminant Animal Digestive Physiology and Nutrition. Waveland Press, Long Grove, IL.

Carter, R. R., and W. L. Grovum. 1990. A review of the physiological significance of hypertonic body fluids on feed intake and ruminal function: salivation, motility and microbes. J. Anim Sci. 68: 2811-2832.

Center, A. M. R. 2011. Fuel and Grian Historic Comparisons. United States Department of Agriculture.

Choat, W. T., C. R. Krehbiel, M. S. Brown, G. C. Duff, D. A. Walker, and D. R. Gill. 2002. Effects of restricted versus conventional dietary adaptation on feedlot performance, carcass characteristics, site and extent of digestion, digesta kinetics, and ruminal metabolism. J. Anim Sci. 80: 2726-2739.

Cooper-Prado, M. J., N. M. Long, E. C. Wright, C. L. Goad, and R. P. Wettemann. 2011. Relationship of ruminal temperature with parturition and estrus of beef cows. J. Anim Sci. 89: 1020-1027.

Cooper, R., T. Kopfenstein, R. Stock and C. Parrott. 1998. Observations on acidosis through continual feed intake and ruminal pH monitoring. .

Cooper, R. J., T. J. Klopfenstein, R. A. Stock, C. T. Milton, D. W. Herold, and J. C. Parrott. 1999. Effects of imposed feed intake variation on acidosis and performance of finishing steers. J. Anim Sci. 77: 1093-1099.

Corrigan, M. E., G. E. Erickson, T. J. Klopfenstein, K. J. Vander Pol, M. A. Greenquist, and M. K. Luebbe. 2007. Effect of Corn Processing and Wet Distillers Grains Inclusion Level in Finishing Diets, University of Nebraska, Lincoln, NE.

Crawford, G. I., C. D. Keeler, J. J. Wagner, C. R. Krehbiel, G. E. Erickson, M. B. Crombie, and G. A. Nunnery. 2008. Effects of calcium magnesium carbonate and roughage level on feedlot performance, ruminal metabolism, and site and extent of digestion in steers fed high-grain diets. J. Anim Sci. 86: 2998-3013.

Depenbusch, B. E., C. M. Coleman, J. J. Higgins, and J. S. Drouillard. 2009. Effects of increasing levels of dried corn distillers grains with solubles on growth performance, carcass characteristics, and meat quality of yearling heifers. J. Anim Sci. 87: 2653-2663.

Depenbusch, B. E., J. S. Drouillard, E. R. Loe, J. J. Higgins, M. E. Corrigan, and M. J. Quinn. 2008. Efficacy of monensin and tylosin in finishing diets based on steam-flaked corn with and without corn wet distillers grains with solubles. J. Anim Sci. 86: 2270-2276.

Eadie, J. M., and S. O. Mann. . 1970. Debelopment of the rumen microbial population: High starch diets and instability. . In: A. T. Phillipson (ed.) Physiology of Digestion and Metabolism in the Ruminant. p 335 - 347. Oriel Press, Newcastle Upon Tyne, U.K.

Erickson, G. E., C. T. Milton, K. C. Fanning, R. J. Cooper, R. S. Swingle, J. C. Parrott, G. Vogel, and T. J. Klopfenstein. 2003. Interaction between bunk management and monensin concentration on finishing performance, feeding behavior, and ruminal metabolism during an acidosis challenge with feedlot cattle. J. Anim Sci. 81: 2869-2879.

Erickson, G. E., T.J. Klopfenstein, D.C. Adams, R.J. Rasby. General Overview of Feeding Corn Milling Co-Procucts to Beef Cattle

Corn Processing Co-Products Manual, A Review of Current Research on Distillers Grains and Corn Gluten. p 3 - 12. University of Nebraska-Lincoln.

Fanning, K., T. Milton, T. Klopfenstein, and M. Klemesrud. 1999. Corn and sorghum distillers grains for finishing cattle, Lincoln, NE.

Firkins, J. L., L. L. Berger, and G. C. Fahey. 1985. Evaluation of Wet and Dry Distillers Grains and Wet and Dry Corn Gluten Feeds for Ruminants. J. Anim Sci. 60: 847-860.

Fox, D. G., R. R. Johnson, R. L. Preston, T. R. Dockerty, and E. W. Klosterman. 1972. Protein and Energy Utilization during Compensatory Growth in Beef Cattle. J. Anim Sci. 34: 310-318.

Fulton, W. R., T. J. Klopfenstein, and R. A. Britton. 1979. Adaptation to High Concentrate Diets by Beef Cattle. I. Adaptation to Corn and Wheat Diets. J. Anim Sci. 49: 775-784.

Goad, D. W., C. L. Goad, and T. G. Nagaraja. 1998. Ruminal microbial and fermentative changes associated with experimentally induced subacute acidosis in steers. J. Anim Sci. 76: 234-241.

Ham, G. A., R. A. Stock, T. J. Klopfenstein, E. M. Larson, D. H. Shain, and R. P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grains with solubles as a source of protein and energy for ruminants. J. Anim Sci. 72: 3246-3257.

Hinders, R. G., and F. G. Owen. 1965. Relation of Ruminal Parakeratosis Development to Volatile Fatty Acid Absorption. J. Dairy Sci. 48: 1069-1073.

Holland, B. P., C.R. Krehbiel, D.L. Step, L.O. Burciaga-Robles, J.J. Cranston, and L. Carlos-Valdez. 2007. Growth Perfomance and Health of Steer Calves Adapted to a High-Concentrate, Program-Fed Diet using Four Methods. Oklahoma State University.

Huffman, R. P., R. A. Stock, M. H. Sindt, and D. H. Shain. 1992. Effect of fat type and forage level on performance of finishing cattle. J. Anim Sci. 70: 3889-3898.

Huls, T. J., M. K. Luebbe, W. A. Griffin, G. E. Erickson, T. J. Klopfenstein, R. A. Stock. 2009. Using Wet Corn Gluten Feed to Adapt Cattle to Finishing Diets, University of Nebraska, Lincoln, NE.

IBC. 2008. Distiller's Grains for Beef Cows Ethanol Coproducts for Cattle. Iowa State University University Extension.

Jenschke, B. E., J. M. James, K. J. Vander Pol, T. J. Klopfenstein, and C. R. Calkins. 2007. WET DISTILLERS GRAINS PLUS SOLUBLES DO NOT INCREASE LIVER-LIKE OFF-FLAVORS IN COOKED BEEF FROM YEARLING STEERS*. J. Muscle Foods 18: 341-348.

Klopfenstein, T., R. ooper, D. J. Jordon, D. shain, T. Milton, C. Calkins, and C. Rossi. 1999. Effects of backgrounding and growing programs on beef carcass quality and yield.

Klopfenstein, T. J., G. E. Erickson, and V. R. Bremer. 2008. BOARD-INVITED REVIEW: Use of distillers by-products in the beef cattle feeding industry. J. Anim Sci. 86: 1223-1231.

Koger, T. J., D. M. Wulf, A. D. Weaver, C. L. Wright, K. E. Tjardes, K. S. Mateo, T. E. Engle, R. J. Maddock, and A. J. Smart. 2010. Influence of feeding various quantities of wet and dry distillers grains to finishing steers on carcass characteristics, meat quality, retail-case life of ground beef, and fatty acid profile of longissimus muscle. J. Anim Sci. 88: 3399-3408.

Krehbiel, C. R., B. P. Holland, and C. T. Milton. 2006. Grain processing effects on management: adaptation diets. In: Proc. of the Oklahoma State University Cattle Grain Processing Symp., Tulsa, Oklahoma. p pp. 156-166.

Krehbiel, C. R., R. A. Britton, D. L. Harmon, T. J. Wester, and R. A. Stock. 1995a. The effects of ruminal acidosis on volatile fatty acid absorption and plasma activities of pancreatic enzymes in lambs. J. Anim Sci. 73: 3111-3121.

Krehbiel, C. R., R. A. Stock, D. H. Shain, C. J. Richards, G. A. Ham, R. A. McCoy, T. J. Klopfenstein, R. A. Britton, and R. P. Huffman. 1995b. Effect of level and type of fat on subacute acidosis in cattle fed dry-rolled corn finishing diets. J. Anim Sci. 73: 2438-2446.

Larson, E. M., R. A. Stock, T. J. Klopfenstein, M. H. Sindt, and R. P. Huffman. 1993. Feeding value of wet distillers byproducts for finishing ruminants. J. Anim Sci. 71: 2228-2236.

Leibovich, J., J. T. Vasconcelos, and M. L. Galyean. 2009. Effects of corn processing method in diets containing sorghum wet distillers grain plus solubles on performance and carcass characteristics of finishing beef cattle and on in vitro fermentation of diets. J. Anim Sci. 87: 2124-2132.

Lodge, S., R. Stock, T. Klopfenstein, D. Herold. 1996. Digestibility of Wet and Dry Distillers Grains from the Fermentation of Corn or Sorghum, University of Nebraska, Lincoln, NE.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997a. Evaluation of corn and sorghum distillers byproducts. J. Anim Sci. 75: 37-43.

Lodge, S. L., R. A. Stock, T. J. Klopfenstein, D. H. Shain, and D. W. Herold. 1997b. Evaluation of wet distillers composite for finishing ruminants. J. Anim Sci. 75: 44-50.

Loy, T., T. Klopfenstein, G. Erickson, and C. Macken. 2003. Evaluation of DDGS in High Forage Diets and Effect of Supplementation Frequency

University of Nebraska, Lincoln, Nebraska.

Loza, P. L., K. J. Vander Pol, G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2005. Effects of feeding a By-Product Combination consisting of Wet Distillers Grains and Wet Corn Gluten Feed to Feedlot Cattle, University of Nebraska, Lincoln, NE.

Ludden, P. A., M. J. Cecava, and K. S. Hendrix. 1995. The value of soybean hulls as a replacement for corn in beef cattle diets formulated with or without added fat. J. Anim Sci. 73: 2706-2711.

Lunn, D. E., T. Mutsvangwa, N. E. Odongo, T. F. Duffield, R. Bagg, P. Dick, G. Vessie, and B. W. McBride. 2005. Effect of monensin on meal frequency during sub-acute ruminal acidosis in dairy cows. Can. J. Anim. Sci. 85: 247-249.

Mader, T. L., J. B. Gaughan, and B. A. Young. 1999. Feedlot Diet Roughage Level for Hereford Cattle Exposed to Excessive Heat Load1. Prof. Anim. Sci. 15: 53-62.

Mader, T. L., S. M. Holt, G. L. Hahn, M. S. Davis, and D. E. Spiers. 2002. Feeding strategies for managing heat load in feedlot cattle. J. Anim Sci. 80: 2373-2382.

Morris, S. E. 2005. The Effects of Dried Distillers Grains on Heifers Consuming Low or High Quality Forage, University of Nebraska, Lincoln, NE.

Nagaraja, T. G., T. B. Avery, E. E. Bartley, S. J. Galitzer, and A. D. Dayton. 1981. Prevention of Lactic Acidosis in Cattle by Lasalocid or Monensin. J. Anim Sci. 53: 206-216.

Nagaraja, T. G., and E. C. Titgemeyer. 2007. Ruminal Acidosis in Beef Cattle: The Current Microbiological and Nutritional Outlook and. J. Dairy Sci. 90: E17-E38.

NRC. 1980. Mineral Tolerance of Domestic Animals. National Academy of Sciences, Washington D.C.

NRC. 2000. Minerals 7th ed. ed. Natl. Acad. Press, Washington, DC.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1998. Acidosis in cattle: a review. J. Anim Sci. 76: 275-286.

Owens, F. N. a. A. L. G. 1993.

The Ruminant Animal Digestive Physiology and Nutrition. Waveland Press, Inc., Long Grove, IL.

Parsons, C. H., J. T. Vasconcelos, R. S. Swingle, P. J. Defoor, G. A. Nunnery, G. B. Salyer, and M. L. Galyean. 2007. Effects of wet corn gluten feed and roughage levels on performance, carcass characteristics, and feeding behavior of feedlot cattle. J. Anim Sci. 85: 3079-3089.

Pritchard, R. H., and K. W. Bruns. 2003. Controlling variation in feed intake through bunk management. J. Anim Sci. 81: E133-E138.

Quinn, M. J., M. L. May, N. DiLorenzo, C. H. Ponce, D. R. Smith, S. L. Parr, and M. L. Galyean. 2011. Effects of roughage source and distillers grain concentration on beef cattle finishing performance, carcass characteristics, and in vitro fermentation. J. Anim Sci. 89: 2631-2642.

Raun, N. S., and W. Burroughs. 1962. Suction Strainer Technique in Obtaining Rumen Fluid Samples from Intact Lambs. J. Anim Sci. 21: 454-457.

Roeber, D. L., R. K. Gill, and A. DiCostanzo. 2005. Meat quality responses to feeding distiller's grains to finishing Holstein steers. J. Anim Sci. 83: 2455-2460.

Rolfe, K. M., G. E. Erickson, T. J. Klopfenstein, J. T. Vasconcelos. 2010. Effects of Using Wet Distillers Grains with Solubles to Adapt Cattle to Finishing Diets on Feed Intake, Ruminal pH, and Ruminal Hydrogen Sulfide Concentration, University of Nebraska, Lincoln, NE.

Rose-Dye, T. K., L. O. Burciaga-Robles, C. R. Krehbiel, D. L. Step, R. W. Fulton, A. W. Confer, and C. J. Richards. 2011. Rumen temperature change monitored with remote rumen temperature boluses after challenges with bovine viral diarrhea virus and Mannheimia haemolytica. J. Anim Sci. 89: 1193-1200.

Sarturi, J. O., G. E. Erickson, T. J. Klopfenstein, J. T. Vasconcelos, M. G. Dibb, K. Rolfe. 2011. Effects of Adaptation Diets containing Wet Distillers Grains With Solubles or Wet Corn Gluten Feed on Ruminal pH, Intake and Hydrogen Sulfide, University of Nebraska, Lincoln, NE.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, D. J. Gibb, D. H. Crews, Jr., D. D. Hickman, M. Streeter, and T. A. McAllister. 2003. Effect of bunk management on feeding behavior, ruminal acidosis and performance of feedlot cattle: A review. J. Anim Sci. 81: E149-158.

Schwartzkopf-Genswein, K. S., K. A. Beauchemin, T. A. McAllister, D. J. Gibb, M. Streeter, and A. D. Kennedy. 2004. Effect of feed delivery fluctuations and feeding time on ruminal

acidosis, growth performance, and feeding behavior of feedlot cattle. J. Anim Sci. 82: 3357-3365.

Scott, T., T. Klopfen stein, R. Stock, and R. Cooper. . 1998. Metabolism and digestibility of corn bran and corn steep liquor/distillers solubles. . Neb. Beef Cattle Rep. MP 69-A: 69-71.

Service, E. R. 2010. Corn Used for Ethanol: Feed Grains Database Custom Query; Supply and Use, Utilization for Alcohol in Fuel, Corn, United States, Market year, 1986-2010.

Spires, H. R., A. Olmsted, L. L. Berger, J. P. Fontenot, D. R. Gill, J. G. Riley, M. I. Wray, and R. A. Zinn. 1990. Efficacy of laidlomycin propionate for increasing rate and efficiency of gain by feedlot cattle. J. Anim Sci. 68: 3382-3391.

Stalker, L. A., T. J. Klopfenstein, D. C. Adams, and G. E. Erickson. 2004. Urea Inclusion in Forage Based Diets Containing Dried Distillers Grains, University of Nebraska, Lincoln, Lincoln, Nebraska.

Stock, R. A., J. M. Lewis, T. J. Klopfenstein, and C. T. Milton. . 1999. Review of new information on the use of wet and dry milling feed byproducts in feedlot diets. In: Proc. Am. Soc. Anim. Sci.

Stock, R. A., M. H. Sindt, J. C. Parrott, and F. K. Goedeken. 1990. Effects of grain type, roughage level and monensin level on finishing cattle performance. J. Anim Sci. 68: 3441-3455.

Sutton, J. D., M. S. Dhanoa, S. V. Morant, J. France, D. J. Napper, and E. Schuller. 2003. Rates of Production of Acetate, Propionate, and Butyrate in the Rumen of Lactating Dairy Cows Given Normal and Low-Roughage Diets. J. Dairy Sci. 86: 3620-3633.

Tremere, A. W., W.G. Merrill, J.K. Loosli. . 1968. Adaptation to High Concentrate Feeding as Related to Acidosis and Digestive Disturbance in Dairy Heifers. J. Dairy Sci. 51: 1065.

Uwituze, S., G. L. Parsons, M. K. Shelor, B. E. Depenbusch, K. K. Karges, M. L. Gibson, C. D. Reinhardt, J. J. Higgins, and J. S. Drouillard. 2010. Evaluation of dried distillers grains and roughage source in steam-flaked corn finishing diets. J. Anim Sci. 88: 258-274.

Vander Pol, K. J., G.E. Erickson, T.J. Klopfenstein, C.N. Macken. 2004. Effects of Wet and Dry Distillers Grains Plus Solubles and Supplemental Fat Level on Performance of Yearling Finishing Cattle

University of Nebraska, Lincoln, NE.

Vander Pol, K. J., G.E. Erickson, T.J. Klopfenstein. 2005. Degradable Intake Protein in finishing Diets containing Dried Distillers Grains, University of Nebraska, Lincoln, NE.

Vander Pol, K. J., M. K. Luebbe, G. I. Crawford, G. E. Erickson, and T. J. Klopfenstein. 2009. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of corn processing coproducts, or supplemental corn oil. J. Anim Sci. 87: 639-652.

Vanness, S. J., T. J. Klopfenstein, G. E. Erickson, K. K. Karges. 2009. Sulfur in Distiller's Grains, University of Nebraska, Lincoln, NE.

Vasconcelos, J. T., and M. L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. J. Anim Sci. 85: 2772-2781.

Wahrmund, J. 2011. Remote ruminal temperature monitoring in feedlot cattle: Effects of bovine respiratory disease, ruminal acidosis, and inclusion of dietary beta-adrenergic agonists., Oklahoma State University, Stillwater, Oklahoma.

Waller, J., T. Klopfenstein, and M. Poos. 1980. Distillers Feeds as Protein Sources for Growing Ruminants. J. Anim Sci. 51: 1154-1167.

Wilken, M. E., M. K. Luebbe, G. E. Erickson, T. J. Klopfenstein, J. R. Benton. 2009. Effects of Feeding Hihg Levels of Byproducts in Different Combinations to Finishing Steers, University of Nebraska, Lincoln, NE.

Yokoyama, M. T., and K. A. Johnson. 1993. The Ruminant Animal Digestive Physiology and Nutrition. Waveland Press, Long Grove, IL.

Zinn, R. A. 1989. Influence of Level and Source of Dietary Fat on Its Comparative Feeding Value in Finishing Diets for Feedlot Steers: Metabolism. J. Anim Sci. 67: 1038-1049.

Zinn, R. A. 1991. Comparative feeding value of steam-flaked corn and sorghum in finishing diets supplemented with or without sodium bicarbonate. J. Anim Sci. 69: 905-916.

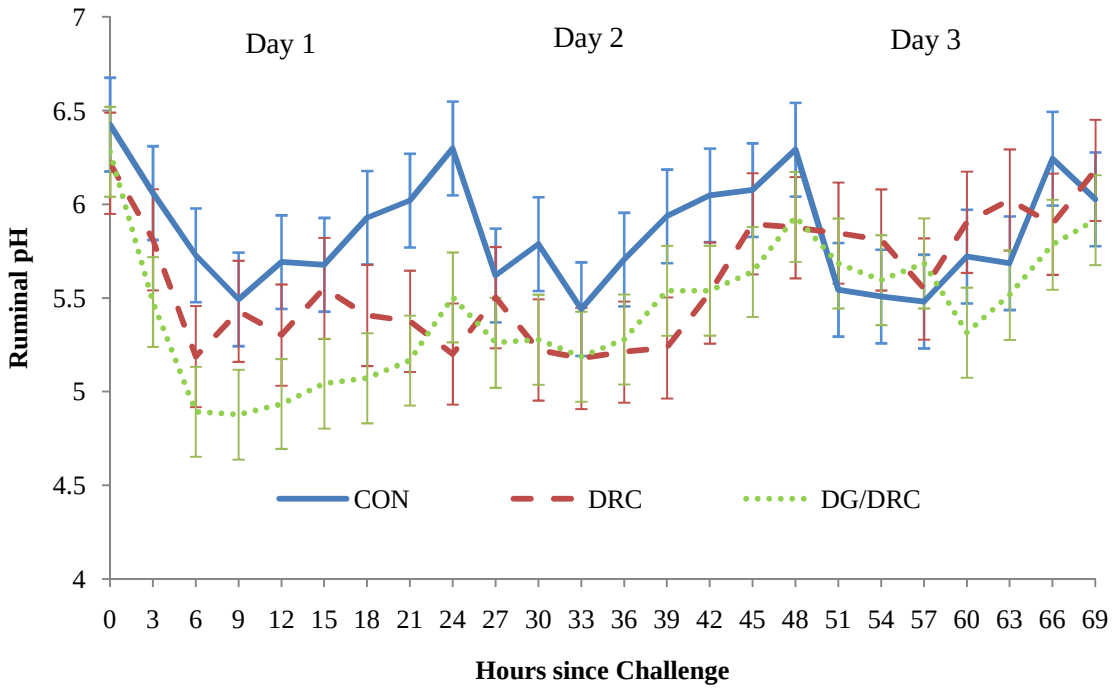

Figure 4.1 Measurement of ruminal pH for acidosis challenge treatments CON, no dietary change, DRC, 100% daily intake replaced with dry rolled corn, and DG/DRC, 50:50 ratio of wet distillers grains with solubles to dry rolled corn. taken by the bolus during the 3-day challenge period.

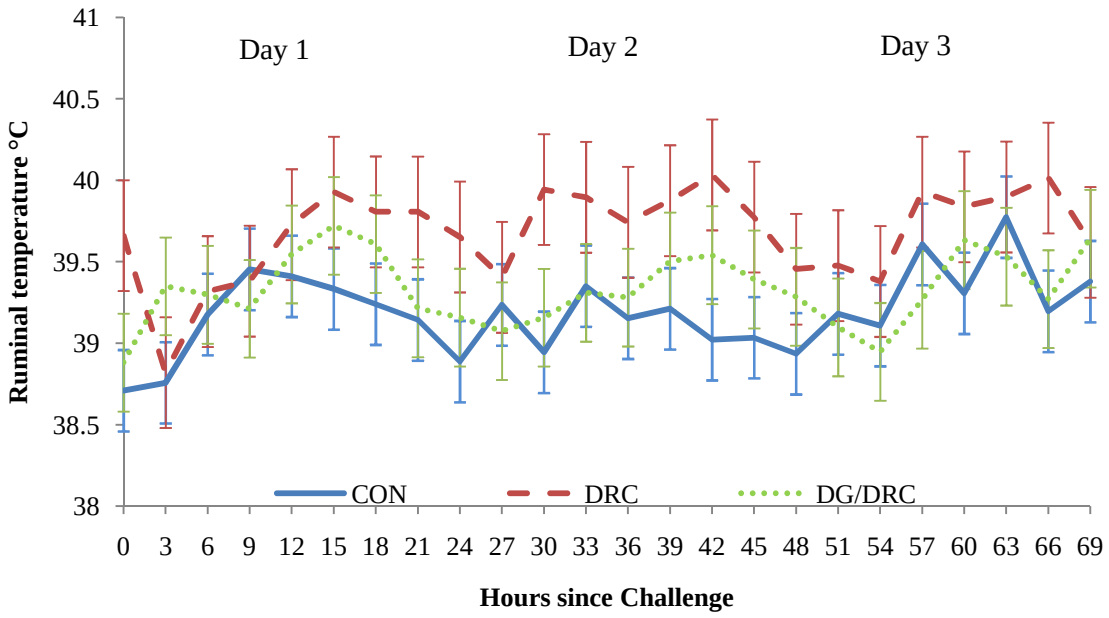

Figure 4.2 Measurement of ruminal temperature for acidosis challenge treatments CON, no dietary change, DRC, 100% daily intake replaced with dry rolled corn, and DG/DRC, 50:50 ratio of wet distillers grains with solubles to dry rolled corn. taken by the bolus during the 3-day challenge period.

Table 4.1. Formulated Ingredient and Chemical Composition

	Challenge Treatments		
Ingredient	CON	DRC	MIX
Dry Rolled Corn	33.75	100	50
WDGS	25	-	50
Prairie Hay	30	-	-
Alfalfa Hay	5	-	-
Supplement[a]	6.25	-	-
Nutrient Composition		-	-
DM %	66.2	-	-
NE_m Megcal/CWT.	77.87	-	-
NE_g Megcal/CWT.	47.47	-	-
TDN %	78.59	-	-
Fat	5.01	-	-
Crude Fiber	14.54	-	-
ADF	21	-	-
NDF	31.49	-	-
Calcium	0.92	-	-
Phosphorus	0.37	-	-

[a] Formulated to contain the following ingredients (DM basis): 41.12% Corn dent No. 2, 16.0% Wheat Midds, 5.12% Urea, 4.08% Potassium Chloride, 26.4% Limestone-38%, 4.0% Salt, 0.03% Manganous Oxide, 0.24% Zinc Sulfate, 1.60% Magnesium Oxide, 0.06% Vit. A-30,000, .04% Vit. E-50%, 0.30% Rumensin-80, and .18% Tylan-40.

[b] All values are calculated and expressed on a 100% DM basis.

Table 4.2. Correlations between ruminal pH and ruminal temperature (RT) of steers subjected to an acidosis challenge.

	Comparisons			
	Ruminal pH[2] vs. RT		Ruminal pH vs. Fluid pH[3]	
Item[1]	r	*P* - Value	r	*P* - Value
CON				
d 1	-0.79	<0.01	0.82	<0.01
d 2	-0.56	<0.01	0.83	<0.01
d 3	-0.72	<0.01	0.67	<0.01
DRC				
d 1	-0.13	0.56	0.67	<0.01
d 2	-0.16	0.45	0.63	<0.01
d 3	-0.59	<0.01	0.42	0.02
DG/DRC				
d 1	-0.60	<0.01	0.84	<0.01
d 2	0.53	<0.01	0.63	<0.01
d 3	0.26	0.13	0.79	<0.01

[1]Acidosis challenge treatment: CON, no dietary change; DRC, 100% daily intake replaced with dry rolled corn; DG/DRC, 50:50 ratio of wet distillers' grains with solubles to dry rolled corn. All treatments were provided CON diet on d 2 and 3.
[2]Ruminal pH measurements taken by ruminal bolus.
[3]Ruminal fluid obtained by suction through tubing equipped with a strainer through incisions in the cannula caps.

Table 4.3. Mean and Maximum ruminal pH and ruminal temperature values each day of challenge period when steers were subjected to an acidosis challenge.

	Day of Challenge Period		
	d 1	d 2	d 3
Item			
CON[3]			
Mean pH	5.87	5.86	5.81
Nadir pH	5.49	5.44	5.48
Mean temperature	39.15	39.10	39.31
Max temperature	39.45	39.35	39.77
DRC[4]			
Mean pH	5.53	5.37	5.88
Nadir pH	5.18	5.17	5.54
Mean temperature	39.55	39.79	39.70
Max temperature	39.92	40.03	40.01
DG/DRC[5]			
Mean pH	5.21	5.40	5.67
Nadir pH	4.87	5.18	5.31
Mean temperature	39.35	39.30	39.33
Max temperature	39.72	39.54	39.64

[3]CON = Control treatment
[4]DRC = 100% dry rolled corn treatment
[5]DG/DRC = 50% wet distillers' grains + solubles and 50% dry rolled corn

Table 4.4. Time spent above and below ruminal pH and ruminal temperature thresholds when steers were subjected to an acidosis challenge.

	Treatment[1]		
Item[2]	CON	DRC	DG/DRC
TB pH 5.2[3]			
d 1	0.0	208.3	1250.0
d 2	0.0	208.3	208.3
d 3	0.0	0.0	0.0
TB pH 5.6[4]			
d 1	208.3	1250.0	1458.3
d 2	208.3	1458.3	1458.3
d 3	625.0	208.3	625.0
TA 39.0°C[5]			
d 1	1250.0	1250.0	1458.3
d 2	1250.0	1666.7	1666.7
d 3	1458.3	1666.7	1458.3
TA 39.45°C[6]			
d 1	208.3	833.3	625.0
d 2	0.0	1458.3	416.7
d 3	416.7	1458.3	625.0

[1]Acidosis challenge treatment: CON, no dietary change; DRC, 100% daily intake replaced with dry rolled corn; DG/DRC, 50:50 ratio of wet distillers' grains with solubles to dry rolled corn. All treatments were provided CON diet on d 2 and 3.
[2]Treatment means presented.
[3]TB pH 5.2 = Time below ruminal pH 5.2, min.
[4]TB pH 5.6 = Time below ruminal pH t.6, min.
[5]TA 39.0°C = Time above ruminal temperature 39.0°C, min.
[6]TA 39.45°C = Time above ruminal temperature 39.45°C, min.

APPENDIX

All procedures involving live animals were approved by the

Oklahoma State University Institutional Animal Care and Use Committee.

VITA

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Candidate for the Degree of

Master of Science

Thesis: THE EFFECTS OF DIETARY ADAPTATION PROGRAMS ON FEEDLOT CATTLE PERFORMANCE AND EVALUATION OF RUMINAL MONITORING DEVICES IN AN ACIDOSIS CHALLENGE

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Title of Study: THE EFFECTS OF DIETARY ADAPTATION PROGRAMS ON FEEDLOT CATTLE PERFORMANCE AND EVALUATION OF RUMINAL MONITORING DEVICES IN AN ACIDOSIS CHALLENGE

Pages in Study: 85 Candidate for the Degree of Master of Science

Major Field: Animal Science

Objective was to evaluate the performance and carcass characteristics of one hundred forty-four steers fed two diets and two adaptation methods over a 28 d period of adaptation to the finishing diet. Pens were randomly assigned to one of four treatments: traditional diet (TRAD) using the forage step-down (STEP) method, TRAD diet using the two-ration blending (2RB) method, wet distiller's grains with solubles (WDGS) diet (DG) using a WDGS step-down method (STEP), and DG diet using the 2RB method. During adaptation, steers fed DG had lower ($P < 0.01$) BW, DMI, ADG, and G:F than steers fed TRAD. Over the entire feeding period, steers fed DG adapted using STEP and those fed TRAD adapted using 2RB had greater ADG compared to steers fed TRAD adapted using STEP and steers fed DG adapted using 2RB ($P < 0.01$). Greater DMI were achieved for steers fed TRAD compared to steers fed DG ($P < 0.01$); however, there was no effect of adaptation diet or method on feed efficiency during the entire feeding period ($P \leq 0.71$). Steers adapted using STEP had greater marbling scores compared to steers adapted using 2RB ($P = 0.04$). Results show diet type has an effect on the best method of adaptation; however, sulfur levels of the DG diet may have played a role in decreased performance. Steers fed DG during adaptation recovered in the subsequent feed period, performing similar to steers adapted using TRAD. A second experiment was conducted to determine the effects of an acidosis challenge on ruminal pH and temperature using ruminal pH and temperature monitoring devices. Twelve ruminally cannulated steers were offered the control diet at 2% BW/d prior to the challenge and starting 24 h after the challenge. Challenges were ruminal dosing of 2% BW of 65% concentrate diet (CON), a mixture of 50:50 dry rolled corn: wet distillers grains (DG/DRC), or 100% dry rolled corn (DRC) at 0 h. Bolus readings for ruminal pH (RpH) and ruminal temperature (RT) were recorded every minute for 72 h after dosing and compiled in 3 h increments for repeated measure analysis. Rumen pH was taken manually every 3 h for 72 h after dosing and analyzed with a repeated measures analysis. There were significant interactions of treatment × h ($P = 0.05$), treatment × day ($P = 0.02$) and day × h ($P = 0.03$) for RpH. Main effects of treatment and d were not significant ($P \leq 0.48$) for RT, however, there was a quadratic response ($P < 0.01$) at h 9 through 21, h 15 (39.64°C) having greater RT ($P < 0.01$) compared to h 0 levels of RpH 5.2 and 5.6. These results indicate that increased availability of highly fermentable substrates in the rumen result in decreases in RpH and increases in RT. However, the type of fermentable substrate may change the relationship between rumen temperature and pH, particularly when substrates such as distiller's grains that have a low pH are included in the diet.

Advisors Approval_____