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FEEDING ALKALINE TREATED AND PROCESSED CROP RESIDUE TO FEEDLOT CATTLE

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FEEDING ALKALINE TREATED AND PROCESSED CROP RESIDUE TO FEEDLOT CATTLE

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Chemical treatment and decreased particle size are methods used to improve digestibility and utilization of the available nutrients in low quality forages. Previous research has indicated that chemically treated corn residue can take the place of corn when included in finishing rations containing distillers grains. Also, decreasing particle size utilizing methods such as pelleting has been shown to improve DMI and ADG. However, limited research has been completed on use of chemical treatment and pelleting in growing and receiving rations. Also, an ideal distillers inclusion has not yet been identified when including alkaline treated stalks in finishing rations. Therefore, a finishing study, a receiving study, two growing studies, and a digestion study were completed to evaluate the effects of alkaline treatment and pelleting on cattle performance, carcass characteristics, and diet digestibility. For the finishing study, data suggest that feeding 10 or 20% treated corn residue with 40% modified distillers grains plus solubles (MDGS) gives comparable performance and carcass traits compared to a corn based control diet. However, if 20% MDGS is fed no more than 10% treated residue should be included. Growing studies indicated that chemical treatment improved DMI, ADG, and G:F when compared to untreated equivalents. However a greater G:F

improvement (8%) was noted with treated wheat straw, while a 2% improvement was observed for treated corn residue. For the digestion study, chemical treatment was not shown to improve residue digestibility in growing calves. Pelleting was shown to improve DMI and ADG, however better G:F was noted with unpelleted diets fed to growing calves. When a pelleted complete feed was tested as a receiving ration, DMI was improved due to pelleting however ADG and G:F did not surpass observed performance paired with the unpelleted control.

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DEDICATION

This work is dedicated to my late father, Keith Peterson. There have been numerous times I have wished to have your opinions and advice throughout this last year. However, the memory of your extraordinary strength and courage never left, and for that I thank you.

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INTRODUCTION

Throughout history, the majority of beef consumed was slaughtered directly off of grass. However, due to the worlds growing population and continued demand for animal proteins, a significant beef supply cannot be provided solely on roughages. To keep up with increasing demand and to utilize surplus grains, the cattle feeding industry developed in the 1940s and 1950s (Corah, 2008) since diets high in energy increase feed efficiency and growth. In recent history however, corn use as a primary ingredient has been problematic because of food vs. fuel competition. High prices are partially due to ethanol production but were also affected by the drought that encompassed the central portion of the United States. Alternative feedstuffs are needed in order to decrease producers input costs.

More land has been transitioned to farm ground for corn production because of improved profitability. One possible low cost feed alternative resulting from corn production is corn residue. At least 1 kg of residue is produced in the field for each kilogram of grain produced (Fahey et al., 1993; Klopfenstein, 1978). In 2013, an average of 4,034 kg of grain per acre was produced in the United States (NASS, 2014), which means 4,034 kg of corn residue production per acre. The majority of this residue remains in the field post-harvest. With future technological advances in crop production, grain yield will continue to increase resulting in increased residue too. Therefore, a review of literature was completed to understand various ways to optimize the use of corn residue.

Distillers Grains

The rapid growth of the ethanol industry has positively impacted beef cattle production due to the availability of distillers co-products. Two-thirds of corn grain is starch (Stock et al., 2000). Because starch is removed during the distilling process of ethanol production, the nutrients remaining in the corn kernel are increased 3-fold when compared to corn grain (Klopfenstein, 2008). With the addition of starch to high forage diets, ruminal organic acid production is increased (Burrin and Britton, 1986). Decreased ruminal pH leads to competition between starch and fiber fermenting bacteria, and consequently decreased fiber digestion (Stalker et al., 2010). However due to absence of starch, distillers grains do not cause negative associative effects on fiber digestion (Stalker et al., 2010), and reduce the risk of acidosis (Stock et al., 1990). Corn-coproducts contain highly digestible fiber that does not disrupt digestibility of forage fiber (Stalker et al. 2010), improving overall dietary forage digestion and utilization.

Wet distillers grains (35% DM; WDG) can be dried to create modified distillers grains (50% DM; MDG) as well as dried distillers grains (90% DM; DDG). However, moisture level impacts performance. According to a meta-analysis by Bremer et al. (2011), WDGS contains 130-143% the feeding value of corn across inclusion levels. In the same analysis, MDGS were found to be 117-124% that of corn, while DDGS was 112% of corn over all evaluated concentration levels (Bremer et al., 2011). Dry matter intake has been shown to increase with increasing distillers DM% while improvements in ADG and G:F are noted with increasing moisture content (Firkens et al., 1985; Nuttelman et al., 2011) indicating a response to increased dietary energy. An eight study meta-analysis completed by Bremer et al. (2008) compared various dietary inclusions of

WDGS (0-50%, DM basis). Dry matter intake was greatest at the 20% inclusion level (10.33 kg/d) with the highest ADG being observed at the 30% level. However, a linear increase was observed for G:F with greatest efficiency (0.174) noted at the 50% level. In all diets, WDGS was shown to have an improved feeding value (126-145%) when compared to the corn based control. In a study by Vander Pol (2006), greatest ADG and G:F was observed with 30 and 40% WDGS inclusion with optimal ADG occurring at 30% and maximum efficiency at 40%. Despite increased cattle performance, some have found decreased DM and OM digestibility in distillers grain diets when compared to corn based (May, 2008; Corrigan et al., 2009; Vander Pol et al., 2009). However, Corrigan et al. (2009) speculated that decreased digestibilities were most likely due to increased intake of the WDGS diets leading to increased passage rates and therefore decreased digestibility.

Lipids Distillers grains contain a high lipid content of approximately 11.9% according to a six plant average collected by Buckner et al. (2011). This high fat content could be partially responsible for increased feeding value when compared to corn. However, if large amounts of distillers are fed, DMI may be inhibited if dietary fat exceeds 8% (Zinn, 1994). Because corn is the initial product of the distillers grain process, its seems practical to assume that corn oil and distillers lipids would be comparably metabolized. However, Vander Pol et al. (2009) compared dry rolled corn (DRC) diets with supplemental corn oil with a WDGS based diet. Corn oil was added to the diets to create a fat content similar to that of the distillers grains diets. It was concluded that fat provided from WDGS and corn oil were digested differently. Total tract digestibility of fat as well as DMI in the WDGS diet was greater when compared to

DRC with corn oil. This occurrence was due to increased ruminal hydrogenation of the corn oil fatty acids when compared to the lipids in WDGS. Additionally, Duckett et al. (2002) stated that additional corn oil inclusion led to increased ruminal biohydrogenation of 18- carbon unsaturated fatty acids. Plascencia et al. (2003) explained that reduced intestinal digestibility of fat is due to extensive ruminal biohydrogenation. However, fat found within distillers grains may be partially protected from complete ruminal biohydrogenation, allowing for an increased fatty acid flow to the duodenum (Vander Pol et al., 2009). Nutrients absorbed in the small intestine can be utilized by the animal more efficiently (Vander Pol et al., 2009), which could explain the increase in feeding value.

Due to corn oil removal for separate marketing, recent research exploring effects of de-oiled distillers grain (9% fat; DM basis) has been completed. Jolly et al. (2013) studied the outcome of feeding 40% inclusion of MDGS with oil (11.8% fat) and with corn-oil removal (9.2% fat). Cattle fed MDGS regardless of fat content had improved final BW, ADG, G:F, and HCW when compared to the corn based control ($P < 0.02$). However, no differences due to MDGS fat content were detected ($P > 0.44$). In the same study, comparable results were observed when comparing de-oiled condensed distillers solubles (6.0% fat; CDS) to normal CDS (21.1% fat). In a similar study by Jolly et al. (2014) normal (12.4% fat) and de-oiled WDGS (7.9% fat) were fed at three inclusions (35%, 50%, 65%; DM basis). Gain of cattle fed de-oiled WDGS diets was increased by 1% ($P < 0.01$) when compared to those consuming normal WDGS based diets. However, DMI for de-oiled cattle was numerically improved by 4% ($P = 0.52$) creating a 2.6% numerical G:F improvement ($P = 0.58$) for cattle fed normal WDGS. To summarize, feeding distillers grains after removal of 22 to 36% of the total fat does not statistically

impact performance. From this it can be concluded that minimal fat removal does not impact DGS performance when compared to a corn based control diet.

Protein Distillers is considered a protein source if fed at 15 to 20% of the diet. However, unlike many other sources of protein, over half of CP in DGS is undegradable in the rumen (undegradable intake protein, UIP). Distillers grains are approximately 63% UIP (Lopez, 2012), subsequently when included in diets as an energy source (>20% dietary inclusion) deficiencies in degradable intake protein (DIP) and metabolizable protein excess occur (Klopfenstein, 2008). Cattle are capable of recycling excess MP to rumen as a source of DIP, therefore supplemental urea is not always required. Stalker et al. (2004) tested the effect of added urea to diets with additional MP from DDG and found that urea did not improve performance when compared to DDG diets. Jenkins et al. (2011) completed two finishing studies where urea supplementation in DGS diets was tested. In the first experiment, factors included DDG (10 or 20%; DM basis) either with or without supplemental urea. Urea was added at 0 or 0.80% for 10% DDG diets and 0 or 0.63% for the 20% DDG diets. Diets containing supplemental urea were formulated to meet predicted DIP requirement following urea addition. Supplemental urea did not affect ($P > 0.40$) performance, however a 3.5% numerical G:F improvement was noted for heifers fed urea and 10% DDG when compared to those fed 10% DDG with no supplemental urea. Similarly, numerical increases were observed for final BW (1.2%) and ADG (4.8%). This data implies that at 20% DDG, adequate amounts of urea are being recycled, and DIP requirements are being met. However, for with diets containing only 10% DDG additional dietary urea is necessary. For the second experiment (Jenkins et al., 2011), urea was supplemented at 0, 0.5, and 1.0% to diets containing DRC and

either 10 or 25% WDGS. All diets were DIP deficient except the one containing urea at 1.0%. No differences due to urea inclusion were detected for DMI, carcass adjusted ADG, final BW ($P > 0.30$), or G:F ($P > 0.11$). This suggests that when DGS are fed at inclusions greater than 20% (DM basis), recycled urea is an adequate source of DIP supporting the results of the first experiment.

Sulfur Distillers grains contain an exceptional amount of sulfur (0.79% DM basis; Buckner et al., 2008) because of sulfuric acid use during fermentation and cleaning throughout the dry-milling process (Vanness et al., 2009). Evidence from Gould (1998) and Sarturi et al. (2013) indicates that sulfur toxicity can negatively impact animal performance and health due to the potential development of polioencephamalacia (PEM). Sarturi et al. (2013) observed decreased DMI and ADG in cattle consuming diets high in sulfur. The National Research Council (1996) recommends that sulfur levels not exceed 0.40% of dietary DM. However, Vanness et al. (2009) and analyzed PEM risk with increasing dietary S levels and reported a low PEM incidence (0.14%) up to dietary sulfur level of 0.46% (Nichols et al., 2012). However, increasing dietary roughage amount may reduce the negative impacts of sulfur (Nichols et al., 2012; Morine et al., 2014).

Observed performance improvements with feeding distillers grains have been attributed to a variety of factors. Vander Pol et al. (2009) suggested improved cattle gains and efficiency are due to greater propionate production and greater fat digestibility of distillers grains. Ham et al. (1994) stated that corn replacement with distillers grains may cause a shift in organic matter digestion to the small intestine. Previous reports have associated a lower tract digestion shift to improvements in efficiency (Blaxter, 1962;

Black and Tribe, 1973). However, others attribute improved feed efficiency to a reduction in subacute acidosis (Farlin, 1981; Firkens et al., 1985).

Corn Residue as a Roughage Source

Cattle are unique in that they are able to consume a variety of diet combinations ranging in combination from 100% forage to 100% grain. However, due to increased efficiency of production and growth rate, the majority of feedlot diets contain 80 to 85% concentrate (Vasconcelos and Galyean, 2007). Unfortunately, diets high in starch can negatively impact intake and gain (Stock et al., 1990). Adding fiber to feedlot diets reduces the risk of metabolic disorders including acidosis and bloat (Galyean and Goetsch, 1993). Therefore, roughages are typically included at an average 8.3 to 9.0% of the majority of finishing diets in the cattle feeding industry (Vasconcelos and Galyean, 2007). However, in a consulting nutritionist survey it was reported that feedlots year-round roughage averages fall into a range of 0-13.5% of dietary DM (Vasconcelos and Galyean, 2007). Vasconcelos and Galyean., (2007) determined that 100% of feedlot consultants utilize corn as their primary grain ingredient. Because of its high demand in the cattle feeding industry, and other industries such as ethanol production, the amount of corn produced annually must be maintained. According to the USDA, a tendency for increased corn production has been observed over the previous years, and in 2013, a stated 95.3 million acres were planted in the U.S. alone (NASS). For each kilogram of grain produced, at least one kilogram of residue is produced (Klopfenstein, 1978). Burken et al. (2013a) reported that as corn grain yield is increased, corn plant dry matter yield also increases with little effect on nutritive quality. There is no doubt that corn residue is abundant. And with continued improvement in grain hybrids and management

methods, corn residue production will continue to increase making it an obvious roughage option in the feeding industry.

Cell Wall Development. Energy from forage is largely obtained from fermentation of the plant cell wall and solubles by rumen microorganisms. More rapid live weight gain requires a large intake of forage and digestibility of these cell walls (Wilson, 1993). Unlike seeds, vegetative tissues contain a large percentage (35% to 80%) of their OM in the cell walls that provide structural integrity to the plant (Jung and Allen, 1995).

The plant cell wall can be separated into distinct portions. The primary cell wall makes up the outermost cell wall portion and is laid down while other cells are developing and dividing. The primary wall is thin and flexible to allow for elongation of the plant cell. The wall of enlarging plant cells is composed of approximately 30% cellulose, 30% hemicellulose, and 35% pectin with perhaps 1-5% structural protein, on a dry weight basis (Cosgrove, 1997). Cellulose microfibrils linked with hydrogen bonds make up the main portion of the primary wall. Adjacent walls are separated by a middle lamella, which predominantly consists of unstructured pectic substances.

When cell elongation ceases, secondary wall thickening begins. During this phase the cell wall becomes progressively thicker as it grows from the inner edge of the primary wall toward the center of the plant cell (Jung and Allen, 1995). During secondary wall growth, cellulose is still laid down however pectins are no longer being placed. Deposition of the lignin polymer commences with the initiation of secondary wall thickening (Terashima et a., 1993). Inclusion of lignin initially takes place in the middle lamella and the primary wall, and then progresses into the secondary wall. This lignin

deposition process leads to the largest lignin concentration being located in the outer edge of the cell in the primary wall region while the center of the cell remains essentially lignin free. Thus, the more mature a plant becomes, the less digestible it will be.

Carbohydrate Constituents Cellulose is considered a cell wall carbohydrate and is also the most abundant component of the cell wall. The chemical structure of cellulose is a linear polysaccharide polymer consisting of thousands of glucose monosaccharide units connected by beta-acetal linkages. Although cellulose is found in primary and secondary cell walls, the degree of polymerization of cellulose is different in each (McNeil et al., 1984). Baker et al. (1959) defines degree of polymerization as "an estimate of the average number of glucose units per chain forming a sub-unit of a given cellulose. This estimate gives an indication of the composition of the cellulose, or the predominance of short or long chains". As a plant matures, the cell walls are thickened leading to greater polymerization of the plant. The polymer chains then make up the crystalline structure of cellulose. The degree of crystallinity of cellulose has been found to affect the rate of degradation by rumen microbes (Siu, 1951). The greater the degree of crystallinity, the slower microbial cellulose degradation will be (Baker et al., 1959). However, degree of polymerization is not always related to decreased digestibility (Baker et al., 1959).

Hemicellulose is a non-cellulosic carbohydrate whose backbone, complete with β1-4 linkages, is similar to that of cellulose with xyloglucans and arabinoxylans being the most prevalent. Hemicelluloses form a network with cellulose microfibrils by binding with cellulose or attaching contiguous microfibrils, however they are not able to form microfibrils on their own.

Characteristics of Lignin As a general rule, the development of the secondary cell wall is accompanied by lignification. This second wall growth signifies the beginning of plant maturity, which agrees with the paradigm of digestibility decreasing as plant maturity increases. The negative relationship between the digestibility of forage and lignin concentration has been observed for 80 years (Woodman and Stewart, 1932). Lignin has been recognized as a limiting factor of total cell wall digestibility as lignification negatively impacts polysaccharide degradation by rumen microbes (Jung and Deetz, 1993; Chesson, 1993; Akin et al., 1975). However, the rate and extent of cell wall degradation may be influenced by the concentrations of the distinctly separate lignin fractions.

The two distinctive parts of lignin that are covalently bound to forage cell walls are core and noncore lignin (Hartley, 1972; Jung and Deetz, 1993). Core lignins are highly compressed polymeric matrices that form covalent links with hemicelluloses. In order to determine core lignin content, an acid detergent fiber analysis using 72% H_2SO_4 must be completed (acid detergent lignin, ADL; Goering and Van Soest, 1970). The mechanisms by which core lignin places a limit on polysaccharide digestion is most likely due to its physical protection of cell wall carbohydrates as well as its hydrophobic qualitites (Kerley et al., 1988). According to Jung and Deetz (1993) the lack of physical access of hydrolytic enzymes to cell wall polysaccharides due to steric hindrance seems to be a major limiting factor in cell wall degradation. Furthermore, because of lignins hydrophobicity, water is not able to enter the internal portion of the cell wall limiting the attachment of hydrophilic enzymes and other rumen microbes.

Although greater importance is placed on the relationship between core lignin and its effect on digestibility of fiber, noncore lignin concentration has also been found to play a role in limiting fiber digestibility. Noncore lignins are classified as low molecular weight phenolic monomers with the two major phenols being *p*-coumaric and ferulic. Within the noncore lignins, *p*-coumaric acid is predominantly correlated with the core lignin fraction of cell walls whereas ferulic acid primarily links to the hemicellulose fiber fraction (Jung, 1989). Many have stated that noncore lignin may play more of a chemical role in reductions of cell wall polysaccharide digestibility because of anitimicrobial properties. Akin (1982) found that a 0.1% addition of *p*-coumaric and ferulic acid to a rumen fluid medium resulted in increased lag time or reduced microbial growth rates when compared to the control medium. When *p*-coumaric was added at a 0.2% level, degradation of cell walls was prevented when compared to the control where the same tissues were rapidly degraded. Similarly, Jung and Fahey (1984) reported a negative correlation between both p-coumaric and ferulic acids and fiber digestion in sheep when consuming a grass variety when compared to a legume. However, Jung (1985) found ferulic acid to have a greater inhibitory impact on cellulose degradability than *p*-coumaric.

Disruption of the carbohydrate binding lignin structure should lead to greater cell wall polysaccharide digestibility due to increased attachment and infiltration of rumen microbes. Complete core lignin removal from the cell wall with permanganate oxidation was shown to increase the microbial degradation of cell wall polysaccharides (Barton and Akin, 1977). Kerley et al. (1985) determined that if a portion of the total plant lignin is broken down by hydrogen peroxide treatment, this 50% delignification allowed

attachment of rumen microbes leading to rapid degradation of carbohydrates. These data suggest that chemical breakdown of lignin can increase the efficiency of total cell wall degradability.

Effect of NDF on intake, performance, and rumen metabolism Voluntary consumption of feed is a key determinant of cattle performance (Arelovich et al., 2008). Although palatability is an important factor when considering intakes (Grovum, 1988) forage fiber amount (NDF) is considered a valuable predictor of total amount consumed (Van Soest, 1994). Dietary intakes are regulated physiologically by reticulo-rumen fill, and also externally by factors such as chemical composition of the diet (Arelovich et al., 2008). Intakes are negatively impacted and therefore ADG and G:F when NDF is present at high levels (Gill et al. 1981). Conversely when roughage NDF is absent, intake is also reduced and performance suffers (Mertens, 2010). Therefore, it is ideal to have a NDF optimum. Galyean and Defoor (2002) stated that a low roughage inclusion in concentrate diets reduces the potential for digestive upset while maximizing energy intake. In 2001 it was determined the nutritionist majority recommended finishing diets contain anywhere from 4.5 to 13.5% roughage (Galyean and Gleghorn, 2001). However, according to a general nutritionist survey by Vasconcelos and Galyean (2007), the range had been narrowed to 8 to 9% roughage. Woods (1969) compared a complete concentrate diet to others with increasing roughage inclusion. As roughage increased from 0 to 15 percent, the greatest intakes were observed at the 15% inclusion. However the greatest gains and efficiency were observed at the 5% roughage level. Arelovich et al. (2008) concluded that in finishing beef cattle, DMI was increased 0.21 kg/d for every 1% unit increase in dietary NDF within a 7.5 to 35.5% range of dietary NDF. However in the same article, it

was concluded that dairy cow DMI declined by 0.21 kg/d for every 1% NDF unit increase within 22.5 to 45.8% total dietary NDF. Gill et al. (1981) examined increasing roughage blend inclusions from 8 to 24% (1/3 ground alfalfa hay, 2/3 corn silage) of the diet combined with corn (high-moisture, steam-flaked, or a mixture of the two). Once again, the authors observed greater DMI with increasing amounts of roughage while ADG remained constant throughout. The lack of gain improvement resulted in worsened G:F with increasing roughage. Bartle et al. (1994) evaluated the effects of inclusion level (10, 20, 30%, DM basis) as well as roughage source (cottonseed hulls vs. alfalfa) in diets containing steam flaked sorghum. The authors concluded that for both roughages, increasing inclusion resulted in increased DMI. No significant difference in ADG was observed between 10 and 20% alfalfa, however a decrease occurred after increasing inclusion to 30%. In diets containing cottonseed hulls, ADG decreased as inclusion increased.

Consumption of forages is essential as it plays a role in creating the ideal environment essential for proper rumen function. Forage fiber maintains rumen activity by stimulating contractions and creating a location for microbial attachment so they do not leave the rumen prematurely (Tamminga, 1993). Generally speaking, fiber sources are less digestible than starches. Therefore, rumination tends increases with roughage consumption (Welch and Smith, 1969; Dong Ho Bae et al., 1979). Because rumination involves regurgitation from the rumen and then remastication, re-insalivation will occur (Ruckebusch, 1988). Due to the buffering qualities of saliva, occurrence of digestive upset is further reduced (Church, 1988). Diet composition can also affect the ruminal environment, and therefore fiber digestibility. Fiber in forage-based diets has been found

to be more digestible than fiber found in high concentrate finishing rations. Mertens and Loften (1980) observed that supplementing a high forage diet with starchy concentrates increases lag time and decreases fiber digestibility. Most likely the low pH environment created by rapid starch fermentation is not an ideal habitat for fiber digesting microbes (Mertens and Loften, 1980; Tamminga, 1993, Caton and Dhuyvetter, 1997).

Roughage in Finishing Cattle Diets Containing Byproducts

Because starch is removed during the dry milling process, the remaining fiber, protein, and fat portions become more concentrated (Bremer et al., 2008). Furthermore, the moisture content of WDGS and MDGS improves palatability, and reduces separation and sorting of ingredients that are less palatable (Bremer et al., 2008). Also, the protein content of DGS reduces the need for other high protein ingredients (Bremer et al., 2008). Therefore, adequate performance can be achieved by including cheaper forages of lesser quality in distillers grains based feedlot rations. Because dietary fiber is increased when starch is decreased (corn-replaced), corn-milling byproducts can also work to reduce the risk of digestive upset, therefore improving G:F (Klopfenstein, 2001).

Research has been completed on increasing forage content in distillers grains diets. In a study by Hales et al. (2013) the effects of increasing roughage inclusion with alfalfa at 2%, 6%, 10% and 14% of dietary DM were examined. In each instance, increased forage replaced DRC in the diet, while WDGS remained constant at 25%. Dry matter intake increased linearly with increased alfalfa hay inclusion. Final BW, ADG, and G:F responded quadratically, increasing from 2 to 6%, then decreasing from 6 to 14% alfalfa hay inclusion. Loza et al. (2010) evaluated effects of increasing concentrations of alfalfa hay (0.0, 2.5, 5.0, 7.5%; DM basis) in diets containing

increasing concentrations of sweet bran and WDGS. A tendency for DMI improvement ($P = 0.06$) was observed with 7.5% alfalfa hay when compared to diets with less, however roughage level did not affect ADG or G:F. When comparing a 0% roughage inclusion to 7.5% within a diet containing a 75% byproduct blend, 33% of cattle consuming the diet containing no roughage were removed for PEM. A meta-analysis completed by Nichols et al. (2012) concluded that as roughage levels increase in finishing rations, risk of PEM decreases accordingly. Roughage inclusion in high byproduct diets may inhibit negative effects associated with H_2S due to its ability to control rumen pH (Morine et al., 2014).

Addition of roughage NDF generally leads to improved DMI which may lead to an increased energy intake in many cases. However, it is important that diets are formulated to meet a NDF optimum inclusion so that intakes and gain are maximized (Galyean and Defoor, 2003). Shain et al. (1999) compared performance of yearling steers fed diets with no roughage to diets formulated to provide equal amounts of NDF from alfalfa or wheat straw. Roughage diets contained either 10% alfalfa (42.8% NDF) or 5.2% wheat straw (82.0% NDF), so diets contained approximately 4.27% NDF from roughage, with DRC as a primary ingredient. The authors observed that roughage addition increased DMI, however there were no DMI differences between the two roughage treatments. Increased ADG and improved G:F was observed in cattle consuming the alfalfa diet, however no differences in ADG and G:F were detected between the wheat straw and no roughage diet. This indicates that replacing a high quality forage source with one of lower quality on an NDF basis may not result in comparable cattle performance in diets containing DRC. However, others have had

greater success utilizing the NDF replacement strategy in distillers grains based diets. Benton et al. (2007) evaluated high or low inclusions of varying roughage sources (alfalfa hay, corn silage, or corn stalks) providing equivalent concentrations of roughage NDF in diets containing 30% WDGS. Alfalfa hay was included at 4 or 8%, corn silage at 6 or 12%, and corn stalks 3 or 6% of diet DM. Low inclusion diets contained approximately 2.46% NDF while the high inclusion diets contained approximately 4.93% NDF from roughage sources. Both DMI and ADG were improved with roughage addition when compared to the 0% roughage control. Significant differences in G:F were not apparent between roughage level and source, illustrating the impact that distillers grains have when included in diets containing low quality roughages.

Research has evaluated the effects of distillers grains on NDF digestibility. Corrigan et al. (2009) found that NDF apparent total tract digestibility did not vary ($P = 0.80$) when 40% WDGS was compared to 0% in HMC, DRC, and SFC diets. Similarly Vander Pol et al. (2009) found that NDF total tract digestibility did not differ between 40 WDGS and a DRC based control. Conversely, Ham et al. (1994) conducted a metabolism study where NDF total tract digestibility for a WDGS diet was significantly greater ($P < 0.10$) than that associated with a DRC control. Vander Pol et al. (2009) discovered that a 40% WDGS diet maintained an increased NDF ruminal digestibility when compared to a DRC based control. Nuttelman et al. (2011) noted that when 40% distillers grains (WDGS, MDGS, or DDGS) diets were compared, no difference in NDF digestibility was detected between distillers grains types, however a corn based control diet had a lower NDF digestibility ($P < 0.06$) when compared to WDGS and DDGS. Other studies have also noted a lack of significance when comparing NDF digestibility between distillers

and corn based diets (Bremer et al., 2010; Pesta et al., 2012). It can be concluded that despite decreased digestibility with increased NDF inclusion, the cattle were still utilizing the dietary nutrients in the same way. Furthermore, distillers grains contain highly digestible fiber which does not compete with microbes when it comes to digestion of forage fiber.

Chemical Treatment

The abundance of crop residues makes it a logical ruminant feed source, however when grain is harvested, the residues have matured to a state of high lignification. Research has been completed indicating increases in digestible fiber with chemical treatment, along with improvements in DMI, ADG, and G:F (Klopfenstein, 1978; Berger et al., 1979; Galyean and Goetsch, 1993). Treatment of straw with NaOH was first tested in Germany during the 1880s. During the period of 1890 to 1917 all treatment methods with sodium hydroxide were based around the assumption that boiling followed by a washing process was necessary to achieve improved digestibilities (Homb, 1984). However, in a paper by Fingerling (1924) it was stated that a low coal supply initiated studies of cold treatment with NaOH. “Geheimrat” E. Beckmann at Kaiser Wilhelm-Institut near Berlin developed the original method of NaOH treatment without boiling (Homb, 1984). The original Beckmann method required the straw to be soaked in a 1.5-2% NaOH solution for 3 days to make up for the low temperature (Homb, 1984). The Beckmann method was found to increase OM digestibility of rye straw from 45.7% in untreated straw to 71.2% in treated straw with a NaOH inclusion of 1.5% (Homb, 1984).

Higher usage rates of NaOH inclusion were not tested in this study. Although there are several advantages to this process (Fingerling, 1924), there were two major disadvantages. The wastewater was contaminated with residual NaOH making it harmful to the environment, and because the treated forages were washed before feeding, a large portion of the solubilized fiber was lost (Fahey et al., 1993). However, Thomann (1921) found that out of the DM that was retained, almost all of the cellulose remained while 20-30% of the lignin and 8-15% of the polysaccharides were found to disappear. In the 130 years since this primary chemical treatment research was completed, chemical treatments have dramatically improved. Although techniques have changed, the motives of chemical treatment have remained the same. A number of chemicals have been tested, but what qualities should the ideal chemical possess? Owen et al. (1984) stated that the ideal chemical should: 1) be effective in improving digestibility and/or intake, 2) be economically feasible when comparing the cost of treatment to improved nutritive value, 3) be readily available and remain available, 4) be non-toxic to animals and the environment, 5) should be a nutrient in itself that is required by the animal, and 6) be non-hazardous to handle and non-corrosive to machinery. Although there are physical forms of treatment available in addition to chemical, the hydrolytic and oxidative chemical processes will be primarily focused on in this section. Physical forms of treatment will be discussed later.

Forage Response to Treatment. Feed characteristics that should be considered for chemical treatment are plant maturity as well as whether the plant is classified as a monocot or dicot. Older, more lignified plants are considered ideal for chemical treatment since no benefits of chemical treatment have been observed with cell solubles. If the plant

in question is not lignified and the cell soluble components are readily available, a negative effect will most likely be observed following treatment (Atwell, 1990). When plant family is considered, monocots have a greater concentration of both *p*-coumaric and ferulic acid. The presence of these phenols suggests that a large number of polysaccharide-lignin bonds are present. Conversely, in dicots polysaccharides and lignins exist in in independent sections of the plant (Fahey et al. 1993). Some have determined that alkaline treatment of dicots is less effective, suggesting that ester bonds of the lignin-hemicellulose complexes in dicots are less prominent than those in monocots (Ben-Ghedalia et al., 1982). However, some uncertainty still remains as to whether the lignin in monocots and dicots differs enough to affect fiber utilization (Fahey et al., 1993).

Hydrolytic treatment Voluntary intake, ADG, G:F, and digestibility, are often enhanced by chemical treatments (Galyean and Goetsch, 1993). Specifically however, hydrolytic forms of treatment (NaOH, NH_3, $Ca(OH)_2$) have been shown to increase digestibility by chemically altering the natural arrangements and bonding of cell wall components. Fahey et al. (1993) stated that this occurs mainly by disrupting the lignin-hemicellulose matrix. Hydrolytic agents are able to solubilize a portion of the hemicellulose while the cellulose content remains virtually unchanged (Klopfenstein, 1978), along with the lignin content (Berger, 1979; Klopfenstein et al., 1972; Ololade et al., 1970). Klopfenstein (1978) summarized that the hydrolytic treatment mode of action involves: 1) solubilization of hemicellulose, 2) increasing extent of cellulose and hemicellulose digestion and 3) increasing rates of cellulose and hemicellulose digestion.

Some of the earliest experiments testing chemically treated forages involved sodium hydroxide (Homb, 1984; Fingerling, 1924). Because of its historical presence and efficacy, NaOH can be considered a cornerstone in the world of chemical treatment. In a 24 study summary, Fahey et. al (1993) states that following treatment with NaOH, DM intake of crop residue was improved by 22%. In the same review, the results of 32 studies examining NaOH treated crop residues reported a 30% increase in DM digestibility. Klopfenstein et al. (1972) found that treatment of corn cobs with 4% NaOH increased DM digestibility by 11.2% when compared to the non-treated control. However, in vitro DM digestibility was found to increase 9.7% when in vivo only increased by 2.5%. Similarly, Berger et al. (1979) found that in vitro DM digestibility improved with increasing level of NaOH treatment but was found to be greater than in vivo at the 4% NaOH level. It is possible that the excess sodium intake occurring with NaOH treated forages may have a negative effect on digestion thereby explaining why in vivo results are less than in vitros. With increasing NaOH inclusion, there is also an observed decrease in rumen retention time leading to an increasing escape of potentially digestible fiber (Berger, 1979). Willms et al. (1991) established that steers fed an alkaline hydrogen peroxide-treated wheat straw (AHPWS) showed a decrease in DM intake when compared to a corn silage control. The same steers also had decreased ADG and feed efficiency compared to the control ration. The poor performance of the AHPWS diet was partly attributed to increased maintenance requirements caused by wetter pens due to increased urination. The authors also stated another factor impacting performance could have been the negative impacts of increased Na and K intakes on ionophores. Similarly, Spears and

Harvey (1987) reported that increasing Na and K in the presence of lasalocid was shown to decrease ADG and increase F:G.

To avoid the potential risks associated with NaOH treatment, treatment with NH_3 can be utilized. Ammoniation is another form of hydrolytic treatment whose added value as a protein source makes it practical (Klopfenstein, 1978) despite the fact that its added digestibility is lower than that of treatment with NaOH (Males, 1987). However, ammoniation has still been proven to improve both intakes and digestibility (Fahey et al., 1993; Morris and Mowat, 1980). In a twenty-one study summary, Fahey et al. (1993), compared NH_3 treated crop residues to untreated and observed that DMI was increased by 22%. A thirty-two study summary (Fahey et al., 1993) indicated a 15% increase in DM digestibility following treatment with ammonia. Another positive attribute is its role in reducing mandatory protein supplementation. Sundstøl and Coxworth (1984) showed that treatment with NH_3 was an effective method of decreasing the amount of supplemental protein normally required with treated residue diets. When treatment with NH_3 is compared to NaOH, there is little doubt that treatment via ammoniation increases safety while reducing labor. The gaseous form of NH_3 reduces physical contact with the chemical, and the process of fumigating a tightly covered bale stack minimizes the handling and processing of the residue. Sundstøl and Coxworth (1984) concluded that the efficacy of the process is determined by the amount of NH_3 used, length of treatment, the DM content and type of material being treated. In a study completed by Morris and Mowat (1980), data were collected on yearling steers fed ground and/or ammoniated corn stover. Treatments consisted of untreated chopped, untreated ground, ammoniated chopped, and ammoniated ground. Urea was added to the untreated rations to make

treatments isonitrogenous. With both chopped and ground rations, ammoniation increased intake of DM by 22%. Ammoniation was also found to increase DM, OM, and NDF digestibility by 9%, 9%, and 14%, respectively. Paterson et al. (1981) completed lamb digestibility and steer growth trials to assess NH_3 treatment of cornstalks. In trial 1, cornstalks were treated with either 0, 2, 3, or 4 g NH_3/100 g of DM. The lambs DMI was shown to increase with increasing addition of NH_3. Digestibility of DM improved from 36.8 to 47.0% with 2% NH_3, however further improvements were not observed with the 3 and 4% levels. In the second trial, growing steers were offered stalks collected on two separate harvest dates that were either treated or not treated with ammonia. Steers fed corn stalks harvested immediately after high-moisture corn showed increased DMI and ADG. Feed efficiency numerically favored steers offered the early harvest stalks, however significant differences ($P > 0.10$) were not detected. Ammoniation was shown to increase ADG and G:F in both early and late harvest stalks when compared to stalks that were untreated. Ammoniation of wheat straw was tested in a study completed by Zorilla-Rios et al. (1985). The 3.5% NH_3 treatment was shown to increase crude protein content from 4.6% to 9.3%. Also improved was IVDMD, increasing to 47.6% when compared to the control at 37.3%. However, no differences were observed for NDF, ADF, or hemicellulose content. Ammoniation was shown to improve voluntary intake of treated straw by greater than 30% as well as to increase fragility of the wheat straw. Fragility is thought to lead to increased intakes because of ease of mechanical breakdown and therefore a more rapid rate of passage (Allen and Mertens, 1987). Ammoniation can be an effective form of chemical treatment, especially if an increase in dietary protein is

desired. However, there are other readily available feedstuffs that are also a good source of protein without having to complete the ammoniation process.

The use of calcium hydroxide was previously avoided because early work suggested it was ineffective when used individually (Bass et al., 1982). Waller and Klopfenstein (1975) (as cited by Klopfenstein, 1978) noted that 4% treatment of corn cobs with sodium hydroxide created considerably greater gains than cobs treated with 4% calcium oxide. However, it's positive attributes include safer handling, less chemical expense, it leaves behind no Na residue (Owen, 1984), and the Ca residual is beneficial to the animal (Rounds et al., 1976). Initial work using $Ca(OH)_2$ in combination with NaOH was found to positively surpass the performance observed when NaOH was used individually for treatment. Rounds et al. (1976) concluded that when corn cobs were treated and ensiled with 3% NaOH plus 1% $Ca(OH)_2$ there was an increase in daily gain, dry matter intake, and feed efficiency when compared to those treated with only 4% NaOH. In a study by Waller and Klopfenstein (1975) it was evident that the sodium and calcium hydroxide combination created higher overall daily gains as well as improved efficiencies when compared to either of the hydroxides individual performance in growing calves. In the same study (Waller and Klopfenstein, 1975), the combination was also evaluated in sheep which confirmed a 3:1 treatment ratio ($NaOH:Ca(OH)_2$) outperformed a treatment combination of 4:0. Waller (1976) (cited by Klopfenstein, 1978) concluded that cellulose digestion was 75.7% when treated with a calcium and sodium hydroxide combination. When used individually, digestion of cellulose was at 71.7 and 71.0% for sodium and calcium hydroxide respectively. Klopfenstein and Owen (1981) summarized performance data from two growth trials utilizing treated wheat straw

(supplemented with protein, Ca, and P) completed by Asadpour (1978). It was noted that straw treated with calcium and ammonium hydroxide resulted in improved daily gains and feed conversions when compared to the untreated control. Lambs fed only ammonia or an ammonia/calcium combination had improved efficiencies compared to those consuming straw treated with only $Ca(OH)_2$. There was no significant difference between digestibility of straw diets treated with either 4 or 5% $Ca(OH)_2$, however an ADG advantage was observed for the straw treated with 5% $Ca(OH)_2$. When compared to the control, individual $Ca(OH)_2$ treatment improved DM and NDF digestibility by an average increase of 9.0 and 9.9% respectively. A numerical increase in DMI, ADG and G:F was also observed in the 4 and 5% $Ca(OH)_2$ treatments.

As a result of these completed studies, it is obvious that varying factors may impact efficacy of chemical treatment. Paterson et al. (1980) conducted lamb digestion trials testing various moisture levels (20, 40, or 60%) of 85% residue diets (cobs, cornstalks, or wheat straw) on digestibility following chemical treatment with 5% $Ca(OH)_2$. Lambs fed corn cobs and wheat straw at 40% moisture numerically had greater DMI, DM and cell wall digestibility when compared to lambs consuming the $Ca(OH)_2$ treated residues at 20 or 60% moisture. Conversely, corn stalk DMI was observed to improve with increasing moisture inclusion while maximal DM and cell wall digestibility was observed at 20%. A second experiment reported by Paterson et al. (1980) assessed the effect of residue moisture on chemical treatment. Stover treated with 5% $Ca(OH)_2$ and containing altering amounts of moisture (25, 30, 35, 40, and 45%) were evaluated. Comparable to the previous experiment, DMI was observed to increase with moisture content within the chemically treated diets. The authors stated that throughout the study it

was observed that residue at 60% moisture fermented, 40% moisture showed traces of mold following 5-10 days of storage, and 20% moisture did not appear to contain enough moisture to elicit a reaction. This was attributed to the dustiness of the diets and the failure of the $Ca(OH)_2$ to attach to the residue. It was recommended that treatment be paired with a moisture level between 20 and 40% to allow for $Ca(OH)_2$ reaction with the residue, but still dry enough so fermentation can be avoided. Shreck (2011) further assessed the effect of low (35%) and high (50%) moisture on corn stover, cobs and wheat straw. The residues were exposed to chemical treatment combinations of either 5:0, 4:1, or 3:2 ($Ca(OH)_2$:NaOH, DM basis, %). Chemical treatment improved IVDMD of all residues, however DMD was greatest for treatments containing NaOH and also for those at 50% moisture. Within 50% moisture, 3% $Ca(OH)_2$:2% NaOH increased IVDMD 14.5% and 10% when compared to 5% CaO for cobs and straw, respectively. The largest IVDMD increase for stalks was observed with the 4:1 treatment. Increases in DMI and overall digestibility from $Ca(OH)_2$ treatment can be attributed to moisture content of the treated forage. Reasearch indicates that 50% is the ideal moisture level that increases microbial attachment and therefore maximizes treatment (Allen and Mertens, 1987; Shreck, 2011). Paterson et al. (1980) evaluated treatment reaction rates. Treatment ratios of 5:0, 1:4, and 3:2 ($Ca(OH)_2$:NaOH, DM basis, %) were applied to corn cobs that were ensiled for varying amounts of time (0, 2, 5, 7, 10, 14, and 21 days). An increase in digestibility from 52% to 28% after 10 days of reaction was observed with 5% $Ca(OH)_2$ treatment, after d 10 no further improvement was noted. Treatment with 1 or 2% NaOH reached maximum digestibility between days 2 and 5 (~70% DMD), and no further improvement was noted after d 5. This work suggests that anaerobic storage will not

improve after storing for more than 6-7 days. Shreck (2011) hypothesized that temperature may effect rate and extent of reaction. Therefore, varying temperatures (30 or 40^{o}C) of anaerobic storage following treatment with either 5% $Ca(OH)_2$ or 3% CaO+2%NaOH was evaluated. Digestibility increased with temperature by approximately 1 percentage unit. However when 3% CaO+2%NaOH was compared to 5% CaO, digestibility was increased 5 percentage units ($P < 0.01$) when NaOH was included across temperatures. Crop residue type, reaction length, moisture level, and perhaps ambient temperature all play a role in efficacy of hydrolytic treatment.

Due to digestibility improvements with CaO treatment, and the complementary nature of distillers grains on digestibility of fiber, finishing studies have been completed evaluating the use of CaO crop residues as a corn replacement. Shreck et al. (2012) evaluated the substitution of corn with 20% treated or untreated crop residues (corn cobs, wheat straw, corn stover) in 40% WDGS diets. Dry matter intake was not different ($P = 0.30$) across treatments. However, alkaline treated wheat straw and corn stover improved ADG by 6.1 and 1.3% compared to the untreated control diet. Similar G:F ($P > 0.05$) was observed between the control and treated stover and straw diets. Another study completed by Shreck et al. (2013) compared different alkaline treated corn stalk and MDGS ratios (2:1 or 3:1; MDGS:treated stalks) in diets containing dry rolled corn. The authors concluded cattle that are fed a maximum of 20% treated residue, at least 25% dry rolled corn, while maintaining a 3:1 ratio of MDGS to CaO treated residue, have similar DMI and ADG when compared to cattle fed 5% untreated roughage and 56% corn. Similarly, Johnson et al. (2013) compared diets with 20% CaO treated or untreated corn stover with to a control diet containing 5% untreated corn residue. All diets contained 40% MDGS.

Similar DMI was observed between treatments ($P > 0.42$), however treated corn residue increased ADG (11.4%) and improved G:F (13.3%) when compared to the untreated corn stover diet. No statistical differences ($P > 0.05$) in ADG or G:F were observed between the control diet and 20% treated corn residue diet. However, treated residue numerically improved G:F by 2.3% when compared to the control diet. This research indicates that CaO treated crop residue can be utilized as a corn replacement. However, the reported studies all contained at least 35% distillers grains. Therefore, the effect of reducing distillers inclusion while utilizing CaO treated crop residue as a corn replacement remain in question.

Oxidative treatment When compared to hydrolytic agents, oxidative agents have increased combustibility and therefore extreme caution must be used during handling. For this reason, many have avoided oxidative treatment of residues. However, Chang and Allen (1971) stated (as cited by Fahey et al., 1993) that oxidative treatments attack and degrade a large percentage of cell wall lignin. This creates the possibility of practicality in improving forage digestibility. Klopfenstein et al. (1972) researched the possibility of using NaOH as well as 4:0 and 4:3 (Na_2O_2:H_2O_2, DM, %) for the treatment of corn cobs fed to wethers. Both DM digestibility and lignin content were improved by NaOH and peroxides when compared to the untreated control. However, in this study there did not appear to be a significant difference between hydrolytic and oxidative, which supports use of hydrolytic treatment.

Physical Treatment Physical alterations can be applied to roughages to increase intakes and efficiency. The first step of fiber breakdown is rumen microbial attachment. Therefore, processes that decrease particle size such as grinding and pelleting crush cell

walls creating more surface area for microbial attack. Grinding increases particle density, which allows for continued flow from the rumen to the small intestine shortly after ingestion (Hooper and Welch, 1985). Because fibrous materials spend less time in the rumen, an increase in voluntary intakes can occur (Minson, 1990) leading to decreased rumen retention. In a study by Pearce and Moir (1964), chaffed roughage was fed to sheep that were either allowed to ruminate normally versus sheep whose rumination was restricted by use of a muzzle as a means to increase ruminal retention time. Increased retention was accompanied by improvements in DM, OM, and crude fiber digestibilities when compared to normal retention. This indicates that increased rate of passage can impede on the time allowed for microbial fiber breakdown, and therefore have a negative impact on digestibility. However, increased intakes and utilization may compensate for decreased digestibility (Van der Honing, 1975). Shain et al. (1996) fed treatments containing equal levels of NDF (alfalfa or straw) ground to a size of 3/8", 3", or 5". Daily gain and efficiencies were improved as particle size was reduced with no significant differences in DMI. Shreck et al. (2011) tested the effects of reduced roughage particle size (1 or 3 inch) of corn stover prior to alkaline chemical treatment. Compared to an untreated 3-inch control, chemical treatment effectively degraded 30% of the forage NDF leading to increased ADG and G:F. When particle size was reduced to 1-inch, ADG and G:F were also improved.

Pelleting is a particle reducing process that may alleviate storage as well as shrink loss issues with roughage handling and processing. Pelleting is also associated with increased intakes. The majority of research completed reports DMI improvements of 8 to 26% when compared to non-pelleted rations (Minson, 1963; Beardsley, 1964; Campling

and Freer, 1966; Minson and Milford, 1968; Coleman et al., 1978). Campling and Freer (1966) examined the effects of grinding and pelleting roughages on voluntary intake and digestibility of dried grass and oat straw. Intakes of pelleted oat straw was 26% greater than that of long straw, while dried grass intakes remained similar. However in both cases, digestibility of ground roughages was lower than that of long roughages. Beardsley (1964) reviewed six studies in which pelleted forage sources were tested against their native forms. Throughout the review, pelleting was shown to increase DMI by at least 8%. In the same review, the author also found that grinding and pelleting forage sources can increase ADG by as much as 100%, and can improve G:F by as much as 35%. McCroskey et al. (1961) tested the use of high and low forage rations that were either pelleted or mixed. Results indicated that if feeding a high roughage diet with low concentrate inclusion, pelleting increases DMI, ADG and G:F. However, if low roughage is fed with a high level of concentrate, feeding a mixed ration is more efficient. Others have observed a decrease in dry matter digestibility when pelleted forages are compared to their normal form (Campling and Freer, 1966; Minson and Milford, 1968; Greenhalgh and Reid, 1973). In a study by Greenhalgh and Reid (1973), pelleting reduced dry matter digestibility by 10 percentage units when compared to the long stem form, while Minson and Milford (1968) observed a 6.8 percentage unit decrease. Decreased digestibility values can most likely be attributed to decreased ruminal retention time because of an increased rate of passage. However, decreased digestibility is often offset by increased DMI. Improved performance often associated with pelleting, as well as elimination of conventional forage use, and transportation and storage ease make pelleting an attractive option.

Based on the reviewed studies, it appears as if crop residues are currently and will continue to remain in abundance. Chemical treatment of residue with CaO is an effective, yet environmentally friendly way to enhance forage digestibility while also supplying a mineral required by the animal. Physical alterations of residue can improve intakes and in some cases DMI and ADG. Distillers grains enhance cattle performance, even with addition of chemically treated residue. However, the majority of the research was completed with diets containing at least 35% distillers grains. It is questionable whether previously observed performance with CaO treated crop residue will be maintained if dietary distillers grains inclusions are decreased. Also, minimal research has been completed on the effects of feeding pelleted, CaO treated crop residue, or a combination to growing calves. Therefore, the objectives of this research were: 1) to compare performance and morbidity of newly received calves fed a complete pelleted feed containing primarily corn residue to those of calves fed a high quality receiving diet, 2) to determine the optimum level of enhanced forage residues and distillers grains in diets on the finishing performance and carcass traits in calf-fed steers, and 3) to determine the effect of feeding pelleted alkaline treated residue to growing calves.

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CHAPTER II. Use of a pelleted corn residue complete feed in receiving diets

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ABSTRACT

A receiving study compared effects of feeding a complete pelleted feed (**PELCR**) to a mixed receiving diet on performance and morbidity of newly received calves. The pellets consisted primarily of corn residue and were designed to replace a conventional grain and forage diet. The study utilized crossbred steer calves (n = 1318; initial BW = 266 ± 1.57 kg) in two separate locations (Agricultural Research and Development Center, ARDC; Panhandle Research and Development Center, PHREC). Within location, steers were blocked by date received and source then assigned randomly to pen. Pens were assigned randomly to a distillers grains based control diet (CON) consisting of 32% distillers grains, 32% dry rolled corn, 32% alfalfa, and 4% supplement or PELCR. A treatment by location interaction was observed for DMI ($P = 0.03$). At PHREC, no difference in DMI was observed (5.8 vs. 5.9 kg/day for CON and PELCR respectively; $P = 0.46$), however DMI was greater for PELCR at ARDC (6.7 vs. 7.0 kg/day for CON and PELCR respectively; $P < 0.01$). No treatment by location interaction was detected for ADG or G:F ($P > 0.18$). The PELCR decreased ADG and G:F ($P < 0.01$) compared to the CON. Morbidity tended to be less ($P = 0.13$) for PELCR. Receiving calves on PELCR may have a positive effect on DMI, but a negative effect on ADG and G:F when compared to a traditional receiving diet. However, use of the complete feed may result in reduced morbidity for high-risk calves.

Key Words: beef cattle, corn residue, pellet, receiving

INTRODUCTION

There are many challenges to consider when receiving new calves into feedlots. For example, stressors from weaning, marketing and transportation may cause loss of appetite, shrink or loss of body mass (Hutcheson and Cole, 1986), compromised digestive and rumen function, and a challenged immune system (Loerch and Fluharty, 1999). Hutcheson (1980) noted that appetite remains depressed during the first 1 to 3 weeks following arrival. Nutrition and stress interact in different ways, 1) stress produces or aggravates nutrient deficiencies, and 2) nutritional deficiencies prevent the animal's ability to respond to a stress (Hutcheson and Cole, 1986). Bovine respiratory disease (BRD), is the greatest health challenge to feedlot cattle in the United States, accounting for 75% of morbidity and 50 to 70% of mortality (Edwards, 1996; Galyean et al., 1999; Loneragan et al., 2001). Approximately 91% of BRD diagnosis in calves occurs within the first 27 d following arrival (Buhman et al., 2000). According to Galyean and Hubbert (1995) a positive correlation between nutrition and health exists, therefore receiving programs need to maximize intakes (~1.5% BW) to improve immune function. Due to potential increased cost and limited availability of forages, alternative sources must be considered.

Because of annual corn yield improvements (Edgerton, 2009), abundant amounts of corn residue make it a practical source to incorporate into feedlot diets. Pelleting corn residue allows for transport from areas with abundant residue to areas with greater cattle numbers (Klopfenstein, 1978), allowing for reduced amounts of traditional forage sources typically needed in feedlots. Additionally, pelleting increases feed intake by 15 to 26% (Beardsley, 1964; Campling and Freer, 1966; Minson and Milford, 1968), which may aid

in reduction of health problems associated with depressed intakes. A complete pelleted feed consisting primarily of corn residue may replace a conventional grain and forage receiving diet, therefore eliminating the need to mix a starter diet. Little research has been completed on feeding complete pelleted feeds to newly received calves. Therefore, the objective of this study was to compare animal performance and incidence of BRD when feeding a complete pelleted feed or a high quality receiving diet commonly used in Nebraska.

MATERIALS AND METHODS

All procedures used for these experiments involving animal care were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

This experiment was replicated at the University of Nebraska-Lincoln Agricultural Research and Development Center (ARDC) near Mead, NE; and the Panhandle Research Extension Center (PHREC) near Mitchell, NE. Calves used in this experiment were purchased from sale barns through order buyers in Nebraska, and were received in October of 2012 at both ARDC and PHREC. Upon arrival, steers were allowed access to water and were processed, weighed, and allocated to treatment within 12 hours. In both locations, initial processing included: individual identification with an ear tag; collection of individual weights; a modified live virus vaccine for IBR, BVD, PI3, respiratory syncytial virus, *mannheimia haemolytica*, and *pasteurella multocida* bacteria (Vista Once, Merck Animal Health, Desoto, KS); injectable anthelmintic (Cydectin Injectable, Boehringer Ingelheim, St. Joseph, MO); and drenched with an oral anthelmintic drench (Safe-Guard, Merck Animal Health, Desoto, KS).

A control receiving diet was included in the study, and was formulated to produce acceptable performance. The control consisted of 32% wet (PHREC) or modified (ARDC) corn distillers grains, 32% alfalfa hay, 32% dry-rolled corn (DRC), and 4% supplement (DM basis; CON), the complete pelleted feed (Iowa Agricultural Bio Fiber, Harlan, IA; PELCR) consisted of 35% corn residue and a blend of grain by-products and minerals (Table 1). The PELCR contained a combination of plant extracts (RumeNext®, ADM, Quincy, IL), whereas CON provided 150 mg/steer daily of monensin (Rumensin, Elanco Animal Health, Indianapolis, IN). Both diets were formulated to provide 125 mg/steer daily of decoquinate (Deccox, Zoetis, Florham Park, NJ). Free-choice hay was not offered in the bunk. Feed bunks were assessed at approximately 0600 h and were managed for ad-libitum intake at both locations. Accrued feed refusals were removed from feed bunks and were dried for 48 h at 60^{O} C in a forced-air oven (Model LBB2-21-1, Despatch, Minneapolis, MN) to determine DM (AOAC, 1999; method 4.2.03). Weekly ingredient samples were collected and analyzed for DM content.

This experiment utilized a total of 1368 newly received steer calves. The Agricultural Research and Development Center received 818 of these over four days (BW = 265 ± 22 kg; 50 pens, average of 16 steers/pen), had eight initial BW blocks according to source and date received, and two diets with 20 replications per treatment. The Panhandle Research and Extension Center received the remaining 550 calves (BW = 264 ± 23 kg; 60 pens, 8 or 13 steers/pen), which were split into 3 blocks by the same process utilized at ARDC. At PHREC, the same two diets were fed, with 30 replications per treatment. This experiment was designed as a generalized randomized block design with two locations. Steers in both locations were assigned randomly within block to pens,

and pen was assigned randomly to treatment. The number of steers per pen was balanced by treatment within block. Calves were fed for 23, 24 or 25 days at ARDC and for 25 days at PHREC in soil surfaced pens. Throughout the study, calves were evaluated daily using the DART system (Holland et al., 2010). Steers meeting one or more of these criteria were treated with an antibiotic approved for treatment of BRD (Micotil, Elanco Animal Health, Indianapolis, IN; Zuprevo, Merck Animal Health, Desoto, KS; Draxxin, Zoetis, Florham Park, NJ) and returned to their pen. At ARDC and PHREC, a total of 4 calves died while on trial. At the end of the receiving period, steers were limit-fed (Watson et al., 2013) a diet consisting of 50% alfalfa and 50% corn gluten feed (ARDC) or 50% WDGS (PHREC) at 2% of the BW for 5-7 days before weighing for ending BW to minimize gut fill variation. Ending BW was an average of 2-day weights (Stock et al. 1983) taken on the final two days of limit feeding.

The net energy equations in the NRC (1996) were used to determine the energy concentration of the CON and PELCR. Dietary TDN of CON was estimated by applying known TDN values (alfalfa, 50%; DRC, 90%; MDGS, 108%) to the dietary components. Then, the energy adjusters were manipulated so that calculated animal performance of CON matched observed animal performance. Subsequently, the energy adjusters used for CON were held constant, and the TDN of PELCR was adjusted until calculated animal performance matched observed animal performance. Therefore, the NE_m and NE_g values for PELCR are relative to CON (Table 1).

Data were analyzed using the MIXED procedure of SAS (Version 9.2, SAS Inst. Inc. Cary, NC). Within location, steers were blocked by source nested within date received, resulting in eight blocks for ARDC and three blocks for PHREC. At ARDC,

each treatment was replicated 20 times, while treatment replication was 30 at PHREC. The number of steers per pen was balanced by treatment within block. Steers that died (n = 4) during the experiment were removed from the analysis. Three of the steers were on the pelleted treatment and causes of death included, a congested heart, BRD, and one death was non-health related. The fourth steer was on the control treatment, and cause of death was Atypical Interstitial Pneumonia. The statistical model included treatment, location, treatment x location interaction, and block nested within location. Morbidity incidence was evaluated as the number of first treatments (number of steers treated in the pen divided by the total number of steers in the pen). Additionally, the rate of two or more treatments was calculated as the number of steers treated two times divided by the total number of steers treated once. Morbidity data were analyzed with the GLIMMIX procedure of SAS using a binomial distribution and a logit-link function.

RESULTS AND DISCUSSION

Throughout the discussion of the results, it is important to note that despite the pelleting difference between the two treatments, dietary composition also varied. In this study, CON was formulated to be a traditional high quality receiving ration. However, PELCR consisted primarily of corn residue and was calculated to provide 86% the net energy of CON. The experimental approach was to compare a new feed product to a common diet that was expected to elicit good performance. Since the diets differed in ingredient composition, physical form (pelleting vs. total mixed ration), and feed additives, the dietary treatments should be evaluated as feeding systems without making inference to dietary ingredients, pelleting, or feed additive use.

A treatment x location interaction was observed for DMI ($P = 0.03$; Table 2). At PHREC, no difference ($P = 0.46$) in DMI was observed. However, at ARDC feeding PELCR resulted in a 4.8% increase ($P < 0.01$) in DMI when compared to CON. The resulting intakes for the current study are interesting, considering the majority of research completed on pelleted feeds reports DMI improvements of 8 to 26% when compared to non-pelleted rations (Beardsley, 1964; Campling and Freer, 1966; Minson and Milford, 1968). In a symposium on forage utilization by Beardsley (1964), six studies were reviewed in which forage sources in their normal form were compared against pelleted forms. In each of the studies, DMI increased by a minimum of 8%. However, the pellet composition consisted of 100% forage. Beardsley (1964) also reviewed several studies in which 100% alfalfa pellets were compared against pellets containing 50-70% alfalfa combined with 30-50% concentrate. These data indicated that pelleted forage containing 30-50% concentrate still resulted in a DMI improvement, however the response was much less than what was observed with the 100% alfalfa pellets. The decreased particle size associated with the pellet likely creates a more rapid rate of passage from the reticulo-rumen allowing for an increase in feed intake. However, when relating these studies to the current experiment, the calves used at both ARDC and PHREC may have had greater overall intakes than what would typically be observed for calves in a receiving situation (DMI = 2.3% of BW for ARDC and PHREC). Therefore, greater overall intakes could have made it more difficult to determine a difference between the two treatments for DMI. Also, the diets were not the same composition. The interaction between treatment and location was evaluated by graphing the amount of DM offered daily at each location. Figures 1 and 2 illustrate daily DM offered to CON and PELCR at

ARDC and PHREC, respectively. At ARDC, DMI for both treatments appear similar over the first 14 days, after which the PELCR intakes continued to increase while CON remained constant (Figure 1). However, at PHREC (Figure 2), DMI for both treatments increased at a comparable rate throughout the trial.

Feeding PELCR resulted in decreased ADG ($P < 0.01$) at both ARDC (-17.6%) and PHREC (-15.1%) compared to CON. This contrasts with studies by Meyer et al. (1959a,b) and Beardsley (1964) in which increased gains (average of 22.3%) were observed with pelleted rations when compared to unpelleted. However, in both scenarios, cattle fed pelleted diets also exhibited significantly increased intakes (average of 17.6% increase), which may have contributed to the noted ADG improvements. Campling and Freer (1966) also examined the effects of grinding and pelleting roughages and reported that although increased DMI was observed, apparent digestibility was decreased when compared to long stemmed roughages. This is supported by data from Greenhalgh and Reid (1973) where pelleting reduced dry matter digestibility by 10 percentage units when compared to the long stem form. Decreased digestibility values are most likely due to decreased ruminal retention time. Typically, apparent digestibility is reduced with pelleted diets, however in the majority of these situations, increased intake of digestible nutrients tends to offset a decrease in digestibility. However, in the current study, dramatic intake improvements were not observed with the pelleted diet, most likely accounting for the reduced ADG. Because PELCR was shown to slightly improve DMI while decreasing overall ADG, G:F was reduced when calves were fed PELCR at both locations (ARDC: 0.247 vs 0.193; PHREC: 0.241 vs 0.200; $P < 0.01$) when compared to CON. Despite differences due to pelleting, dietary ingredient differences between the two

treatments are of significance. The pelleted complete feed (corn residue as a primary ingredient) was compared to a more traditional receiving ration containing distillers grains. Previously, distillers inclusion in receiving diets has been found to increase DMI and ADG (Drouillard et al. 1999). Also, the control diet contained monensin while the pelleted feed contained RumeNext creating a supplement discrepancy. The fact that the pellet did not produce ADG and G:F at the level of the control diet is not surprising, however the observed results noted with the pelleted treatment can be considered acceptable with ADG averaging 1.29 kg and G:F averaging 0.197.

A treatment x location interaction was observed for the percentage of steers pulled two or more times ($P = 0.03$; Table 2). There were no differences ($P = 0.72$) in the percentage of calves treated two or more times at ARDC. However, a decrease ($P = 0.03$) in second pulls at PHREC was observed in the PELCR when compared to CON (1.0 vs. 9.5% of calves pulled two or more times) for PELCR and CON respectively. At PHREC, calves experienced a higher morbidity rate overall ($P < 0.01$). However, the number of steers requiring a second treatment at PHREC was low. At both locations, there was a tendency ($P = 0.13$) for number of calves pulled and treated for BRD at least once to be less for PELCR when compared to CON. The greater incidence of morbidity at PHREC may have negatively influenced DMI and ADG (Gardner et al., 1999). In a review by Rivera et al. (2005) the effect of increasing dietary forage and morbidity from 6 separate studies was analyzed. The regression showed that there was a tendency for morbidity rates to decline when dietary energy concentration was decreased (increased forage amounts). However, the observed change was small (i.e. increasing roughage by 20% would decrease morbidity by 1.35%; Rivera et al., 2005). This observation is supported

by Lofgreen et al. (1975, 1981) who noted increased morbidity as concentrate (dietary energy concentration) was increased from 55 to 90% in receiving diets. However, in contrast to these results, Fluharty and Loerch (1996) found that as dietary concentrate increased from 70 to 85%, morbidity was not affected by diet. For the current study, the energy concentration of PELCR was found to be 86% of CON based on estimates of dietary NEm and NEg (Table 2). Therefore, the observed reduced morbidity may be at least partially related to the reduced dietary energy concentration associated with PELCR.

IMPLICATIONS

Receiving calves on a pelleted residue and byproduct complete feed may have a positive effect on DMI, but a negative effect on ADG and G:F compared to a high-quality receiving diet. Use of pelleted residue may result in reduced morbidity for high-risk calves. While steer performance was less desirable compared to the high quality diet fed in this experiment, steers fed the pelleted residue diet gained 1.29 kg/day with a G:F of approximately 0.192 to 0.200 which is considered acceptable performance when the quality of the control diet is considered. Therefore, receiving calves on a complete feed consisting of pelleted corn residue may be a viable option for producers if it is competitively priced.

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Table 1. Dietary treatment by location fed to received calves

	ARDC		PHREC	
Ingredient, % DM	Control	Pellet[4]	Control	Pellet[4]
WDGS[1]	-	-	32	-
MDGS[1]	32	-	-	-
Alfalfa Hay	32	-	32	-
Dry Rolled Corn	32	-	32	-
Supplement[2,4]	4	-	4	-
Complete Feed[3,4,5]	-	100	-	100
NEm, Mcal/kg	2.07	1.76	2.14	1.94
NEg, Mcal/kg	1.40	1.14	1.44	1.27
Nutrient composition, %				
CP	18.46	15.89	19.30	15.89
NDF	32.83	47.04	25.41	47.04
Ca	0.36	1.28	0.48	1.28
P	0.48	0.68	0.40	0.68
K	1.65	1.40	1.20	1.40
S	0.32	0.40	0.28	0.40
Mg	0.21	0.44	0.28	0.44

[1]WDGS=wet corn distillers grains plus solubles; MDGS=modified corn distillers grains plus solubles

[2]Formulated to provide 150 mg/steer daily monensin (Rumensin, Elano Animal Health, Indianapolis, IN).

[3] Contained a combination of plant extracts (RumeNext, ADM, Quincy, IL).

[4]Formulated to provide 125 mg/steer daily of decoquinate (Deccox, Zoetis, Florham Park, NJ).

[5]Consisted of 35% corn residue and a blend of grain by-products and minerals.

Table 2. Calf performance and health data of steers fed a complete pelleted feed or control diet at two locations

	ARDC[1]		PHREC[1]			*P*-values		
Item	Control[2]	Pellet[2]	Control[2]	Pellet[2]	SEM	Trt[3]	Location[4]	Interaction[5]
Initial BW, kg	265	264	267	268	3.7	0.82	0.05	0.66
Ending BW, kg	305	296	302	298	3.6	<0.01	0.88	0.20
DMI, kg/day	6.70[b]	7.04[a]	5.82[c]	5.88[c]	0.15	<0.01	<0.01	0.03
ADG, kg	1.67	1.38	1.41	1.20	0.07	<0.01	<0.01	0.18
Gain:Feed	0.247	0.193	0.241	0.200	0.003	<0.01	0.75	0.17
Morbidity								
First Pull, %[6]	20.64	17.36	42.18	38.18	0.02	0.13	<0.01	0.85
Second Pull, %[7]	9.52[a]	11.27[a]	9.48[a]	0.95[b]	0.03	0.07	0.03	0.03
Dead, n	1[d]	2[e,f]	0	1[g]	---	---	---	---

[1] ARDC = Agricultural Research and Development Center, Mead, NE; PHREC = Panhandle Research and Extension Center, Mitchell, NE.
[2] Control = 32% Alfalfa, 32% modified or wet distillers grains, 32% dry-rolled corn, 4% supplement
Pellet = complete pelleted feed consisting primarily of corn residue, and a blend of by-products and minerals.
[3]Main effect of treatment.
[4]Main effect of location.
[5]Treatment x location interaction.
[6] Percentage of calves treated once.
[7] Percentage of calves treated two or more times/number of calves treated once.
[a,b,c] Means within a row without a common superscript are different, ($P < 0.05$).
[d] Death due to Bovine Respiratory Disease (BRD).
[e] Death was non-health related.
[f] Death due to Acute Interstitial Pneumonia (AIP).
[g] Death due to congested heart.

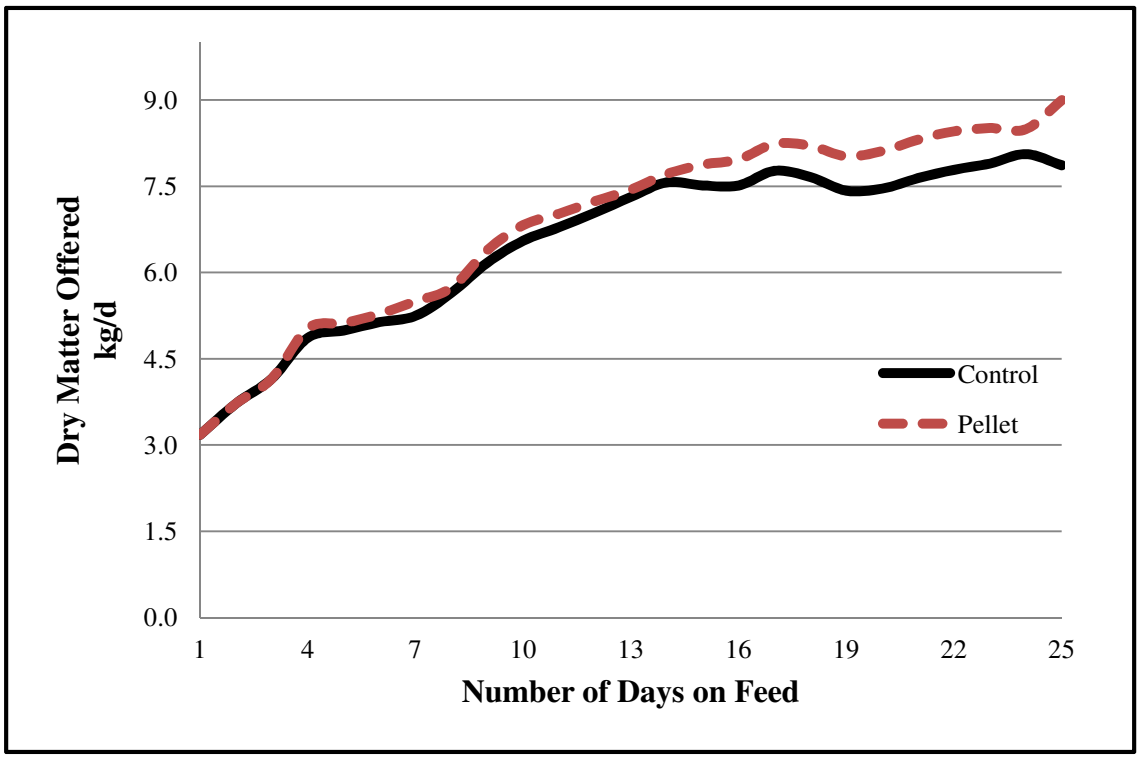

Figure 1. Dry matter feed offered to steers fed at the Agricultural Research and Development Center. The control diet was considered to be a traditional high quality receiving ration and contained: 32% DRC, 32% MDGS or WDGS, 32% alfalfa hay, and 4% supplement. The complete pelleted feed (Iowa Agriculture Biofiber) consisted of 35% corn residue and a blend of grain byproducts and minerals (Treatment x Location; $P = 0.03$).

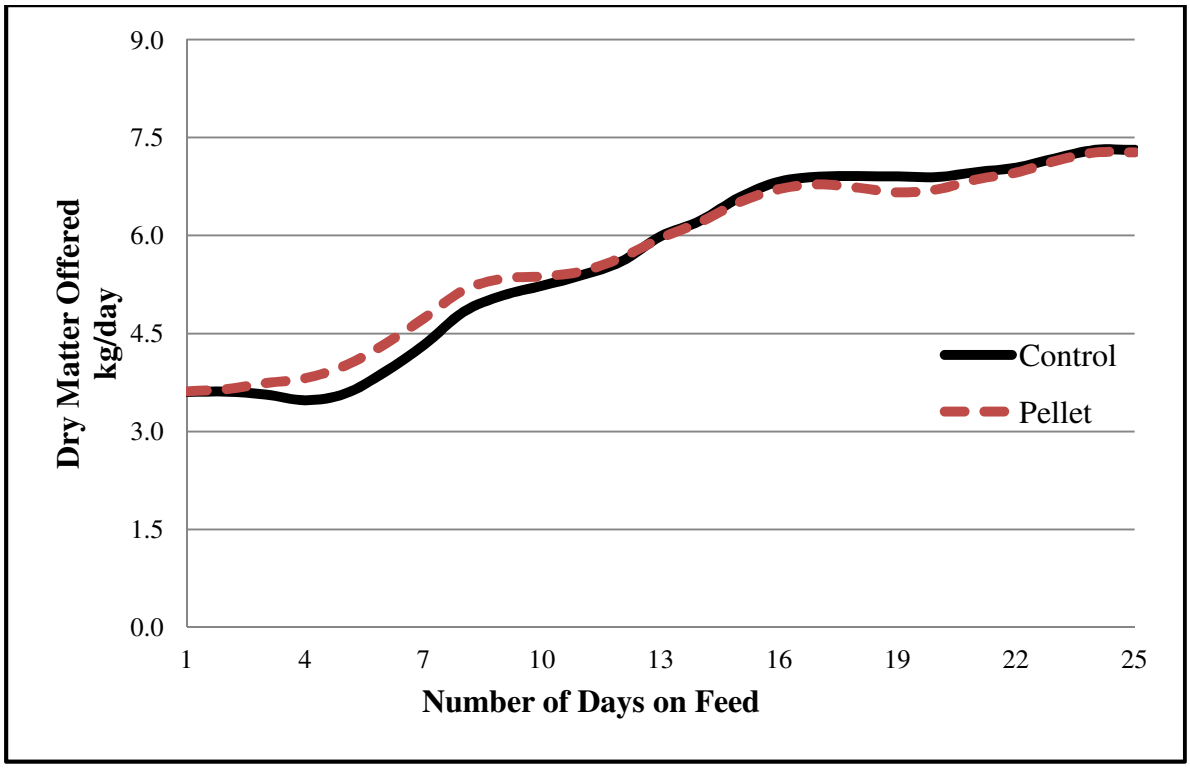

Figure 2. Dry matter feed offered to steers fed at the Panhandle Research and Extension Center. The control diet was considered a high quality receiving ration and contained: 32% DRC, 32% MDGS or WDGS, 32% alfalfa hay, and 4% supplement. The complete pelleted feed (Iowa Agriculture Biofiber) consisted of 35% corn residue and a blend of grain byproducts and minerals.

CHAPTER III. The effects of pelleting and alkaline treatment of low quality crop residues on digestion and performance of growing calves

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ABSTRACT

Three experiments utilized 2 x 2 factorial arrangements of treatments to determine effects of pelleting and alkaline treatment of residues on performance and digestion of steers. In Exp. 1, 480 steers (initial BW = 312 ± 8 kg) evaluated pelleting and alkaline treatment (5% CaO + H_2O vs. none). In Exp. 2, ruminally fistulated yearlings (n = 6; initial BW = 497 ± 25 kg) and calves (n = 6; initial BW = 228 ± 22 kg) evaluated dietary digestibility of 20 or 40% modified distillers grains plus solubles (MDGS) and alkaline treatment (5% CaO + H_2O vs. none). In Exp. 3, 460 steers (initial BW = 331 ± 20 kg) evaluated alkaline treatment (5% CaO + H_2O vs. none) and residue type (corn residue vs. wheat straw). In Exp. 1, pelleting increased DMI, and ADG ($P < 0.01$), but reduced G:F ($P < 0.01$). Alkaline treatment improved DMI, and ADG ($P < 0.01$) and slightly improved G:F ($P < 0.05$). In Exp. 2, CaO did not affect digestibility ($P > 0.37$). Feeding 40% MDGS increased DMD, and OMD ($P < 0.10$) compared to 20% MDGS. In Exp. 3, wheat straw increased DMI and ADG ($P < 0.01$) and tended ($P = 0.07$) to improve G:F compared to corn residue. Alkaline treatment increased DMI and ADG ($P < 0.01$) and tended ($P = 0.06$) to improve G:F compared to untreated. Overall, pelleting increased DMI and ADG but reduced G:F whereas chemical treatment increased ADG and G:F.

Key Words: chemical treatment, corn residue, growing calves, pelleting, wheat straw

INTRODUCTION

Commodity markets are highly variable (NASS, 2014), and in most cases commodity price increases are paired with a production expansion (NASS, 2014). In the case of high corn prices, this situation can negatively impact the supply of hay as land typically used for forage production is converted to land for corn production. Thus, forage supply is reduced and forage prices increase. However, an increase in grain production is paired with an increase in availability of crop residue. Klopfenstein (1978) reported that increases in grain yield results in a proportional increase in the amount of residue. While replacement of higher quality forage sources with corn residue would be less expensive, maturity at the time of grain harvest leads to residue digestibility of approximately 50% or less (Klopfenstein, 1978).

Feeding values of low quality forage sources can be improved by alkaline treatment with calcium oxide. Klopfenstein (1978) stated that chemical treatment increases the extent of cellulose and hemicellulose digestion, while also increasing the rate of digestion. This can likely be attributed to the swelling of the forage, thereby allowing microbial attachment (Tarkow and Feist, 1968). Chemically treated forages have been reported to have increased digestibility when compared to untreated forages (Shreck, 2011), and result in acceptable finishing performance when fed in combination with distillers grains (Shreck, 2012a).

Because the first step of fiber breakdown is rumen microbial attachment, processes that decrease particle size such as grinding and pelleting increase total surface area allowing for faster microbial attachment (Bowman and Firkins, 1993). Decreasing particle size increases density allowing for continued flow from the rumen to the small

intestine shortly after ingestion (Hooper and Welch, 1985). Other research indicates that rate of passage can impede the time allowed for microbial fiber breakdown and therefore have a negative effect on digestibility (Pearce and Moir, 1964). However, it has been observed that increased intakes and utilization may compensate for decreased digestibility (Van der Honing, 1975). Pelleting densifies bulky forages, which allows for forage transport from areas with abundant forage sources to areas with greater cattle numbers. Additionally, it has been observed that reducing particle size prior to calcium oxide treatment improves the feeding value of chemically treated forages (Shreck, 2012b). However, little work has evaluated pelleting and calcium oxide treated forages in growing diets.

The objectives of this research were to: 1) evaluate the effects of calcium oxide treatment of corn residue and pelleting in growing diets containing distillers grains, 2) determine the effects of calcium oxide treatment of forage in combination with MDGS on nutrient digestion in a forage based diet, and 3) evaluate treated wheat straw and corn residue in growing calf diets.

MATERIALS AND METHODS

All procedures used for these experiments involving animal care were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Exp. 1

Four hundred eighty yearling crossbred steers (BW = 313 ± 8 kg) were utilized in an 80-d growing study to determine the effects of calcium oxide treated corn residue and pelleting in diets containing distillers grains on growing calves. Steers were received as calves in October and November, 2012 and initial processing included three individual identifications with tags; collection of individual weights; vaccination with a modified live virus vaccine for IBR, BVD, PI3, respiratory syncytial virus, *mannheimia haemolytica*, and *pasteurella multocida* bacteria (Vista Once, Merck Animal Health, Desoto, KS); injectable anthelmintic (Cydectin Injectable, Boehringer Ingelheim, St. Joseph, MO); and an oral anthelmintic drench (Safe-Guard, Merck Animal Health, Desoto, KS). Cattle were vaccinated approximately 12 d later with a vaccine for pinkeye prevention (Piliguard Pinkeye + 7, Merck Animal Health, Desoto, KS), a booster against viral infections (Vista 5, Merck Animal Health, Desoto, KS), and prophylaxis for BRD associated with *Mannheimia haemolytica*, *Pasteurella* multocida, and *Histophilus somni* (Micotil, Elanco Animal Health, Greenfield, IN). Prior to the start of the study, calves grazed cornstalk residue and received a SweetBran supplementation daily at a rate of 2.27 kg/hd. Ten days prior to the start of the growing study, all cattle were vaccinated for prevention of disease caused by *Clostridium chauvoei*, *septicum*, *novyi*, *sordellii*, *perfringens* Types C & D, and *Haemophilus somnus* (Vision 7/Somnus, Merck Animal Health, De Soto, KS) and were poured for external parasite control (Permectin, Bayer HealthCare, Shawnee Mission, Kansas). Steers were limit fed (Watson et al., 2013) a diet of 50% corn gluten feed and 50% alfalfa (DM basis), at 2% of BW for 5 d prior to the start of the study. Initial BW was collected on d 0 and d 1 of the trial to reduce gut fill

effects (Stock et al., 1983). A randomized block design was utilized with a 2 x 2 treatment factorial. Factors included diets that were either pelleted (Iowa Agricultural BioFibers, Harlan, IA; **PEL**) or unpelleted (**NPEL**) in combination with corn residue that was either alkaline treated (CaO or $Ca(OH)_2$; **TRT**) or residue that remained free of chemical treatment (**UNT**; Table 1). Unpelleted diets contained modified corn distillers grains plus solubles (**MDGS**) to aid in binding of the diet, whereas the pelleted rations contained dried distillers grains plus solubles (**DDGS**) in order to maintain efficacy of the pelleting process. Distillers grains was included at 36% (DM basis) in all of the diets (Table 1). Crop residue for all diets was purchased as round bales prior to the start of the study from the same source. Initially, corn residue to be used for NPEL was tub ground (Mighty Giant, Jones Manufacturing, Beemer NE) through a 7.62 cm screen and stored in a covered commodity bay. Based on research completed by Shreck et al. (2011), crop residues were treated with 5% CaO (DM basis) at 50% DM. Therefore, chemical treatment of NPEL consisted of CaO (5% of total DM; Standard Quicklime, Mississippi Lime Co., Kansas City, MO), and ground residue hydrated to 50% DM with water. Feed trucks dispensed NPEL residue into a concrete bunker that was subsequently covered with plastic. This process was completed every two weeks continuously throughout the trial so that residue treatment occurred at least 7 d prior to feeding. The pelleted residue was treated with 6.6% $Ca(OH)_2$ in place of CaO which provided the same hydroxide units as 5% CaO. Approximately 50% of residue for PEL was treated with a moisture content of 35% prior to being blended with the remainder of the residue and pelleted. Untreated residue was ground and stored in the commodity bay with no added moisture or chemical. Modified distillers grains plus solubles were obtained from a commercial

ethanol plant (Green Plains, Central City, NE) and delivered as needed (approximately 1 semi-load/wk). All growing diets contained 4% supplement formulated to provide 200 mg/steer daily monensin (Elanco Animal Health, Greenfield, IN). All ingredients were weighed and mixed in a Roto-Mix feed truck (Dodge City, KS). Throughout the study, feedbunks were evaluated daily at approximately 6:30 a.m. and were managed so calves were consuming feed at *ad libitum* intake. Accumulated feed refusals were removed from the feed bunks and were dried for 48 h at 60° in a forced-air oven (Model LBB2-21-1, Despatch, Minneapolis, MN) to determine DM (AOAC Method 935.29). Orts were assessed weekly and on average refusals were found to make up less than 1% of the daily total DM offered.

Calcium from limestone was replaced by calcium oxide (71.4% Ca) and calcium hydroxide (69% Ca) in treated diets. On d 1 of the trial, steers were implanted with 36 mg zeranol (Ralgro; Merck Animal Health). Ending BW were collected similar to initial BW, where steers were limit-fed for 5 d the same diet at an estimated 2% of BW and weighed two consecutive days prior to feeding.

Steers were sorted into four weight blocks, stratified by BW within block, and assigned randomly to pens. Each treatment was replicated seven times, with the number of steers per pen being balanced by treatment within block (16 or 24 steers/pen). Each weight block contained one replication with the exception of block 3 which contained four replications. Nine steers were treated for foot rot and one steer died while on study. The steer that died while on trial was removed from the analysis, however the foot rot treated calves remained in the analysis.

Data were analyzed using the MIXED procedure of SAS (Version 9.2, SAS Inst. Inc. Cary, NC) as a generalized randomized block design with pen as the experimental unit. The model included block, effects of pelleting, chemical treatment, and interaction of pelleting and chemical treatment. Significance was established at $P \leq 0.05$ for all values.

Exp. 2

A digestion study was conducted to evaluate rumen metabolism and digestibility of treated crop residue in combination with de-oiled MDGS. Ruminally fistulated yearling steers (n = 6; initial BW = 497 ± 25 kg) and steer calves (n = 6; initial BW = 228 ± 22 kg) were assigned randomly using a row x column transformation (independent squares for yearlings and calves) and acclimated to each diet for four 21-d periods, separated into a 14 d adaptation period and 7 d of collection. This experiment included a 2 x 2 factorial arrangement of treatments. Factors included chemical treatment of corn residue [none (UNT) vs 5.0% CaO + 50.0% moisture (TRT)] and de-oiled MDGS inclusion level (20 vs 40%).

All corn residue for the current study was ground through a 2.54 cm screen. Chemical treatment consisted of CaO (5% of total DM; Standard Quicklime, Mississippi Lime Co., Kansas City, MO), and ground residue hydrated to 50% with water. The residue mixture was combined in a Roto-Mix feed truck (Dodge City, KS), and dispensed into a concrete bunker that was subsequently covered with plastic. This process was completed every two weeks continuously throughout the trial at the Agricultural Research and Development Center (ARDC) Research Feedlot (Ithaca, NE) so that residue treatment occurred at least 7 d prior to feeding. High moisture ingredients (treated residue

and MDGS) were collected from ARDC approximately two times per week, or as needed. Mixed feeds and wet feed ingredients were transported to the Animal Science Complex (Lincoln, NE) in 208 L barrels and stored in a 4° C walk in cooler prior to mixing to maintain quality and prevent mold growth. Diets (Table 2) were mixed in a stationary ribbon mixer (Model S-5 Mixer; H.C. Davis Inc, Bonner Springs, KS). Steers were given *ad libitum* access to feed and were fed once daily at 0800 h. The supplement made up 4% of the diet (DM basis), and was formulated to provide 200 mg/steer daily of monensin (Rumensin-90; Elanco Animal Health) daily. Feed refusals were collected daily prior to feeding from d 14 to 19 within each period. From ort samples, a steer within period sample was composited, and then dried at 60°C in a forced air oven (Model LBB2-21-1, Despatch, Minneapolis, MN) to determine DM content (AOAC Method 935.29). Individual intakes were determined daily by establishing the difference between amount of feed offered and orts collected on a DM basis. Fecal outputs were offset with intakes two days prior to account for a 48 h passage lag (Van Soest, 1994)

Titanium dioxide (TiO_2) was used as an external marker to determine fecal output estimates. All yearlings and calves were dosed intraruminally with 7.5 g of TiO_2 twice daily at 0800 and 1600 hr. Approximately 300 g of feces (rectal grab samples) was collected at 0800, 1200, and 1600 hr from the yearlings throughout the collection period (d 14 to 19). One daily fecal grab sample was collected from the calves throughout the collection period at 0800 hr. All fecal samples were composited on a wet basis into a daily composite, then lyophilized (Virtis Freezmobile 25ES, SP Industries, Warminster, PA). Following the freeze dry process, daily samples for individual animals were composited on a dry basis by period, and stored for analysis.

Dried diet samples, orts, ingredient, and fecal samples were ground to pass through a 2-mm screen using a Wiley mill (No. 4, Thomas Scientific, Swedesboro, NJ). A subsample was then ground using a Wiley mill through a 1-mm screen for laboratory analysis. All samples were composited by period. Diet, orts, ingredient, and fecal samples were analyzed for NDF (Van Soest et al., 1991) and OM. Ash was determined using a muffle furnace set at 600°C for 6 h (AOAC, 1999; method 4.1.10). Organic matter was calculated based on total ash content. Period composites of treated and untreated stalk samples were assayed for *in vitro* NDF digestion analysis using procedures outlined by Goering and Van Soest (1970). Fecal samples were analyzed for Ti concentration according to procedures outlined by Myers et al. (2004). Fecal samples were diluted 10:1 and analyzed for Ti concentration with a sphectrophotometer. Digestibility was caluculated using the following equation: Digestibility (%) = 100 – (100 * feed concentration/digesta concentration) as reported by Owens and Hanson (1992).

Submersible, wireless pH probes (Dascor Inc, Escondido, CA) were placed into the rumen of each yearling to monitor individual ruminal pH on d 12 within each period. Each probe was weighted to ensure the probe remained in the ventral sac of the rumen. Prior to the start of each period pH probes were calibrated by submersing probes in pH 4 and 7 standard solutions. Ruminal pH was recorded over the collection period (d 16-21) every minute continuously for each period. On the first d of each period, prior to the start of the next diet, probes were removed from each animal and the pH data was downloaded and probes were recalibrated. Ruminal pH measurements from each period were adjusted using beginning and ending calibration values to ensure accurate pH measurements.

Data for ruminal pH were analyzed by period using the GLIMMIX procedure of SAS. Data were analyzed as a repeated measures analysis with d repeated and an autoregressive [AR(1)] covariance structure was found to provide best fit (Littell et al., 1998). The model included d and treatment as fixed effects and steer was considered a random effect. Time and area of ruminal pH < 5.6 as well as magnitude of pH change were calculated using the process described by Cooper et al. (1999).

Digestibility and intake data were analyzed using the MIXED procedure of SAS. The model included animal, period, distillers level, and treatment as fixed effects. Main effects of chemical treatment, distillers level, and age as well as the interactions were tested. Significance was established at $P \leq 0.05$ for all values.

Exp. 3

Four hundred sixty yearling crossbred steers (Initial BW = 331 ± 20 kg) were utilized in a 69-d growing study. Steers were received as calves in October and November of 2011, and initial processing included: individual identification with an eartag, collection of individual weights, vaccination for prevention against *Infectious bovine rhinotracheitis,* BVD types I & II, PI_3, and BRSV (Bovi-Shield Gold 5, Pfizer Animal Health, New York, NY), prevention of disease caused by *Clostridium chauvoei*, *septicum, novyi, sordellii, perfringens* Types C & D, and *Haemophilus somnus* (Vision 7 Somnus, Merck Animal Health, De Soto, KS), prevention against disease caused by *Mannheimia (Pasteurella) haemolytica* Type A1 (One Shot, Zoetis, Florham Park, NJ), and prevention against internal and external parasites (Dectomax Injectable, Zoetis, Florham Park, NJ). Following initial processing, steers were vaccinated for prevention of pinkeye (Piliguard Pinkeye + 7, Merck Animal Health, Desoto, KS), and provided a

booster against viral (Bovashield Gold 5, Pfizer Animal Health, New York, NY) and clostridial (Vision-7 Somnus, Merck Animal Health, De Soto, KS) infections. Steers grazed corn residue for approximately 90 d following initial processing until the start of the trial on February 23, 2012. Fifteen days prior to the start of the study, all steers were treated for prevention of internal and external parasites (Phonectin, Bio Agri Mix LP, Mitchell, ON). Steers were limit fed (Watson et al., 2013) a mix containing 47.5% wet corn gluten feed, 47.5% alfalfa hay, and 5% supplement (DM basis) at 2% of BW for 5 d prior to weighing to determine initial BW on d 0 and d 1 (Stock et al., 1983). Treatments (Table 3) were set up in a 2 x 2 factorial arrangement with factors consisting of alkaline treatment (**AT**) or not (**NT**) and residue type as either corn residue or wheat straw. The AT was treated using 5% CaO (standard quicklime; Mississippi Lime Company, Kansas City, Mo) and carried out using a patented process with successive tub grinders (Performance Plus Liquids, Inc., Palmer, NE). Wheat straw was tub ground (Mighty Giant, Jones Manufacturing, Beemer NE) through a 7.62 cm screen. Chemical treatment of wheat straw consisted of CaO (standard quicklime, Mississippi Lime Co.), water, and ground residue, weighed and mixed into feed trucks (Roto-Mix, Dodge City, KS). In both corn residue and wheat straw treatments, the mixture was calculated to be 50% DM with calcium oxide added at 5% of the total DM. Treated corn residue and treated wheat straw DM averaged 57.6 and 49.6%, respectively. Treated residues were both dispensed into a bagger (Model 2W08; Kelly-Ryan, Blain, NE) operating at approximately 1379 kPa for anaerobic storage over the duration of the trial. Treatment of crop residues was completed 30 d prior to the initiation of the trial. Untreated residues were ground and stored in covered commodity bays (no chemical or moisture added). Wet distillers grains

plus solubles were acquired from a nearby commercially producing ethanol plant (Abengoa Bioenergy, York, NE) and delivered as needed (average of 1 semi-load weekly). Treated diets contained sufficient amounts of Ca (3.35% from CaO treatment) and dry meal supplement was included at 1%. Untreated diets had supplement inclusion of 3.0% and limestone was added (1.58% of diet DM) to maintain a Ca:P of 1.2:1. Both supplements were formulated to supply monensin (Elanco Animal Health, Greenfield, IN) at a rate of 200 mg/steer daily. Feedbunks were evaluated daily at approximately 0630 h and cattle were managed for *ad libitum* intake so that only traces of feed were left each morning at feeding. Steers were fed once daily. Accumulated feed refusals were removed from bunks and dried for 48 h at 60°C in a forced-air oven (Model LBB2-21-1, Despatch, Minneapolis, MN) to determine DM content (AOAC Method 935.29). Ingredient samples were collected weekly and DM determined using the same process as used for orts.

Monthly diet composite samples were assayed for *in vitro* DM disappearance (IVDMD; Tilley and Terry, 1963). Inoculum for IVDMD was obtained by collecting a mixture of rumen fluid (strained through four layers of cheesecloth) from two steers consuming a 30% dried distillers grains plus solubles (DDGS) and 70% brome hay diet. Inoculum was mixed with McDougall's buffer at a 1:1 ratio along with 1 gram of urea/L of rumen fluid (McDougall, 1948). A 0.5 g sample was added to a 200 mL test tube and 50 mL of inoculum was added. Test tubes were placed in a water bath at 39°C for 48 h. Fermentation was ceased by adding 6 mL of 20% HCl and 2 mL f 5% pepsin per test tube. Residue was filtered, dried at 100°C, and weighed to determine IVDMD.

The experiment was structured as a generalized randomized block design with three weight blocks (light, medium, heavy). Steers (19/pen) were assigned randomly within block to pens, and pen was assigned randomly to treatment (5 replications/treatment). Each block contained one replication with the exception of block 3 which contained three replications. Data were analyzed using the MIXED procedure of SAS with block as a fixed effect. Main effects of chemical treatment and residue, as well as the interaction were tested. If an interaction was significant ($P < 0.05$), simple effect means were separated with a t-test using the pDiff option. Significance was declared at $P \leq 0.05$ for all values.

RESULTS AND DISCUSSION

Exp. 1

There were no pellet x chemical treatment interactions ($P > 0.18$; Table 4) observed in this experiment. As expected, DMI was greater (12.2 vs. 9.8 kg/d; $P < 0.01$) for PEL diets when compared to NPEL. The large increase in DMI due to pelleting may be related to increased passage rate from reduced particle size of the pellet. Improved DMI with pelleting has been replicated a number of times, with increases ranging from 15 to 26% when compared to mixed rations (Beardsley, 1964; Campling and Freer, 1966; Minson and Milford, 1968). The 25.1% DMI improvement observed in the current study falls within the range observed in previous studies.

Ending BW was greater in cattle fed PEL ($P < 0.01$) compared to NPEL (427 vs. 417 kg respectively). Pelleting improved ADG by 9.1% (1.43 vs. 1.31; $P < 0.01$). Similar outcomes were observed by Meyer et al. (1959a,b) and Beardsley (1964) where increased gains were observed with pelleted rations. However, because the percentage increase for

DMI was greater than that for ADG in the current study, there was an 11% reduction in G:F when PEL was fed (0.133 vs 0.118; $P < 0.01$). Campling and Freer (1966) examined the effects of grinding and pelleting roughages and reported that although increased DMI was observed, apparent digestibility was decreased when compared to long stemmed roughages. This is supported by data from Greenhalgh and Reid (1973) where pelleting reduced DM digestibility by 10 percentage units compared to the long stem form. In a preliminary *in situ* study by Sewell et al. (2009), pelleted corn residue was compared against its native form. The authors observed that *in situ* DM disappearance was improved by 10.5% due to pelleting (data unpublished). Therefore, decreased digestibility values are most likely due to decreased ruminal retention time because of pelleting. However, in the current study and similar to previous work, increased intake of digestible nutrients appeared to offset any decreased digestibility.

As hypothesized, steers consuming TRT had greater ending BW, DMI, and ADG compared to UNT. Chemical treatment of residue with CaO or $Ca(OH)_2$ increased ending BW (428 vs 417 kg; $P < 0.01$). Steers fed TRT had a 6.1% increase in DMI (11.3 vs. 10.7; $P < 0.01$) compared to UNT. Chemical treatment also resulted in a 9.6% increase in ADG (1.43 vs. 1.30; $P < 0.01$) and a 3.9% improvement in G:F (0.128 vs. 0.123; $P < 0.05$) when compared to UNT. These performance improvements remain consistent with previously completed work comparing treated corn residue to untreated (Rounds et al., 1976; Waller, 1976; Shreck, 2012a,b; Johnson et al., 2013) with chemical treatment improving ADG and G:F.

Although no interactions between pelleting and chemical treatment were observed ($P > 0.18$), numerical improvements in ADG and G:F were noted when TRT was used in

combination with PEL. Chemical treatment increased ADG in PEL by 11.1% and by 8.8% in NPEL. Improved G:F due to chemical treatment was 6.1% in PEL and 1.5% in NPEL. The large observed response of treatment in pelleted diets is most likely due to the decreased particle size. Shreck et al. (2012b) evaluated chemical treatment of both 2.54 and 7.62 cm ground corn residue, and found feeding value CaO treated stover was increased with the 2.54 cm grind size. Garrett et al. (1976) applied an alkaline treatment to wheat rice straw via a pelleting process, and reported that ADG and G:F were improved due to chemical treatment and pelleting. However in the current study, the observed G:F improvement by CaO for the unpelleted diets was relatively small compared to previously completed studies. Johnson et al. (2013), and Shreck et al. (2012a,b) observed G:F improvements with CaO treatment ranging from 5 to 17.4% compared to untreated corn residue. However, studies by Johnson et al. (2013) and Shreck et al. (2012a,b) were completed with blends of HMC and DRC in addition to distillers grains and treated residue. Therefore, it can be concluded that high forage diets containing CaO treated forages may not markedly improve G:F of growing cattle efficiency.

Exp. 2

There were no chemical treatment x distillers level interactions ($P \geq 0.67$; Table 5) observed for intakes or digestibilities. Chemical treatment did not impact ($P \geq 0.37$) DM, OM, or NDF digestibilities ($P > 0.30$; Table 5). These results were unexpected when considering previous research. Shreck et al. (2011) observed a 47.2% improvement in *in vitro* dry matter digestibility (IVDMD) of crop residue following treatment with 5% CaO. Similarly, Shreck et al. (2013) observed that when 25% CaO treated or untreated

corn residue was fed with 40% WDGS, DM and OM digestibility were increased by 17.9 and 18.3% respectively ($P < 0.01$) with chemical treatment. For the current study, steers consuming treated diets tended ($P = 0.11$) to have reduced NDF intake compared to steers consuming untreated (8.3 vs. 9.5 kg/day for treated and untreated respectively), while DM intakes were not different (7.0 vs 6.8 kg/d for treated and untreated respectively; $P = 0.79$). Comparably, Shreck et al. (2013) observed a decrease in NDF intake with treated corn residue diets (3.1 vs. 3.7 kg/d). This suggests that treatment with CaO partially solubilized NDF, therefore decreasing NDF intake. Lab analysis of forage used in the current experiment indicated that CaO solublilized NDF by 10 percentage units relative to the untreated residue (Table 6). Presumably treatment with CaO partially solubilized NDF, thereby decreasing NDF intake, as the remaining portion is less digestible. Adjusted NDF values were also included on Table 5. Because the hemicellulose portion of fiber was partially solubilized (primarily cellulose and lignin remaining), it is not part of the initial NDF measurement. However, when cattle consume the treated forage, they are also consuming the solubilized NDF portion. Therefore, for the adjusted NDF values, the calculated NDF value for untreated stalks was used to determine NDF intake of the treated residue diets. This accounts for the fact that the increased digestibility numbers occur within the animal and not prior to the stalks being consumed. After this adjustment, chemical treatment did not impact NDF intake or digestibility statistically ($P > 0.17$). However, numerically cattle offered treated diets consumed more NDF (4794 vs. 4309 g for treated and untreated respectively), and increased digestibility was observed with treated diets (61.3 vs 55.7% for treated and untreated respectively). Overall, greater DM and OM digestibilities were noted with 40

MDGS inclusion ($P \leq 0.05$). Increasing distillers inclusion also increased DM, OM, and NDF intakes ($P \leq 0.05$). Luepp et al. (2009) offered steers ad libitum hay and supplemented dried distillers grains plus solubles (DDGS) at 0, 0.3, 0.6, 0.9, and 1.2% of BW daily. As supplementation of DDGS increased, total dietary OM intake increased linearly ($P < 0.01$), as did total tract OM digestibility ($P < 0.01$). However, NDF intakes remained consistent across treatments ($P > 0.24$). Loy et al. (2003) compared DDGS supplements formulated for low (0.21% BW daily) and high (0.81% BW daily) gain. The authors concluded that with increased daily DDGS supplementation, total DMI was increased by 17.9% ($P < 0.01$). Buckner et al. (2007) observed a trend for increased DMI (3.7%) when MDGS was increased from 15 to 30% (DM basis) in a forage based growing diet.

There was no observed age x treatment interaction ($P > 0.63$). However, significant age differences were observed for DM, OM, and NDF intakes ($P < 0.01$; Table 7) with yearlings consuming more daily when compared to the calves. There a tendency for OM to be more digestible ($P = 0.08$) in yearlings than in calves. Also, numerical DMD and NDFD increases were observed with the yearlings, however the increases were not statistically significant ($P > 0.14$). It is expected that there will be some intake differences due to age. However, as observed in the current experiment, there was still a similar treatment response within both age groups (data not provided).

Interactions were noted for maximum, average, and minimum ruminal pH ($P < 0.01$; Table 8) as untreated residue had greater maximum and average pH within 20 MDGS ($P \leq 0.10$) whereas chemical treatment resulted in similar values within 40 MDGS. Minimal pH data responded similarly ($P \geq 0.26$). This agrees with data from

Shreck et al. (2013) where treated stalks fed with 40% WDGS numerically increased ruminal pH values, since alkaline treated residue will increase ruminal pH.

Our hypothesis for the current study was that dietary inclusion of alkaline treated corn residue would increase diet digestibility when compared to diets with untreated residue in growing diets. It is unclear why treatment with CaO did not improve DM or OM digestibility when considering the results of previous research. Though, consistent with earlier studies, increasing MDGS inclusion increased intakes and digestibilities.

Exp. 3

An interaction ($P < 0.01$) between crop residue and alkaline treatment (Table 8) was observed for ending BW and ADG. The magnitude of response of ADG and ending BW due to alkaline treatment was greater in wheat straw diets compared to corn residue diets. Steers fed treated corn residue had 10.1% greater ADG and 1.3% greater ending BW when compared to untreated corn residue. However, steers fed treated wheat straw diets had increases of 24.3% for ADG and 3.4% for ending BW compared to untreated wheat straw. The observed ADG and ending BW differences of steers fed treated and untreated crop residues are also supported by IVDMD (Table 3) of treated and untreated corn residue (39.6 vs. 38.6% for treated and untreated, respectively) and wheat straw (43.1 vs. 36.1% for treated and untreated, respectively). Steers fed treated wheat straw diets also had greater DMI ($P < 0.01$) and a tendency ($P = 0.07$) for improved G:F when compared to corn residue diets. Overall, alkaline treatment tended ($P = 0.06$) to improve G:F by 6.1% and DMI ($P < 0.01$) by 10.3%. The difference in efficacy of treatment between residue type is likely due to the fact that straw tends to be of lower quality (all stem) when compared to corn residue (leaf and husk). Previous data suggest that lower

quality feed sources often show a greater response to chemical treatment (Klopfenstein and Owen, 1981). Coombe et al. (1979a) and Lesoing (1980) observed that chemically treating wheat straw also produced improved cattle performance. However, the performance improvements observed with treated wheat straw were greater when compared to that of corn residue.

IMPLICATIONS

Chemical treatment was shown to increase DMI, ADG, and to slightly improve G:F of cattle consuming low quality residue in high forage growing diets. However the magnitude of improvement depends on residue type. Because observed G:F was only improved slightly with alkaline treatment, it is unclear if the costs associated with chemical treatment would be offset by improved animal performance when fed to growing calves. When relating the current data to similar studies with treated residue in finishing diets, it appears that less of a response is observed in high forage growing diets. Performance improvements were noted with the pelleting process making it a potential option for producers. However, because G:F was not improved, pellets would have to be favorably priced in order to offset increased intakes.

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Table 1. Ingredient composition of diets fed to growing calves in Exp.1

	Pelleted		Unpelleted	
	Untreated	$Ca(OH)_2$[1]	Untreated	CaO[1]
MDGS/DDGS[2]	36	36	36	36
Treated Residue[3,4]	-	60	-	60
Untreated Residue[3,4]	60	-	60	-
Supplement	4	4	4	4
Fine ground corn	2.4064	3.5234	2.4064	3.5234
Limestone	1.1170	-	1.1170	-
Salt	0.3000	0.3000	0.3000	0.3000
Tallow	0.1000	0.1000	0.1000	0.1000
Trace mineral	0.0500	0.0500	0.0500	0.0500
Vitamin A-D-E	0.0150	0.0150	0.0150	0.0150
Rumensin[5]	0.0116	0.0116	0.0116	0.0116
Nutrient Composition, %				
CP	15.79	16.23	14.76	14.79
NDF	55.44	49.15	60.16	55.06
Ca	0.88	1.60	0.31	2.00
P	0.42	0.40	0.39	0.40

[1] Unpelleted residue treated with 5% CaO (DM basis) after hydration with water to 50% DM at least 7 d prior to feeding. Pelleted residue treated with 6.6% $Ca(OH)_2$ in place of CaO which provided the same hydroxide units as 5% CaO. Approximately 50% of this residue was treated with a moisture content of 35% before being blended with the remainder of the residue and pelleted.

[2]Unpelleted diets contained modified distillers grains plus solubles (MDGS), whereas pelleted diets contained dried distillers grains plus solubles (DDGS).

[3]Pelleted residue was treated with 6.6% $Ca(OH)_2$ in place of 5% CaO.

[4]All baled corn residue originated from the same source.

[5]Formulated to provide 200 mg/steer daily Rumensin

Table 2. Ingredient composition of diets fed to calves and yearlings for Exp. 2

	20 MDGS		40 MDGS	
	Untreated	Treated	Untreated	Treated
MDGS	20	20	40	40
Treated Residue[1,2]	-	76	-	56
Untreated Residue[2]	76	-	56	-
Supplement	4	4	4	4
Fine ground corn	1.68	1.87	3.41	1.87
Limestone	1.19	-	1.11	-
Salt	0.30	0.30	0.30	0.30
Tallow	0.10	0.10	0.10	0.10
Urea	1.65	1.65	-	1.65
Rumensin[3]	0.0116	0.0116	0.0116	0.0116
Trace mineral	0.0500	0.0500	0.0500	0.0500
Vitamin A-D-E	0.0150	0.0150	0.01500	0.0150
Nutrient Composition, %				
CP	10.49	10.53	16.29	16.31
NDF	67.77	61.40	59.59	54.92
Ca	0.38	2.49	0.30	1.85
P	0.27	0.28	0.45	0.46

[1] Treated = Residue treated with 5% CaO (DM basis) after hydration with water to 50% DM at least 7 d prior to feeding, Untreated = no CaO treatment.
[2]All residue ground through a 2.54 cm screen.
[3]Formulated to provide 200 mg/steer daily monensin and 90 mg/steer daily tylosin.

Table 3. Dry matter and nutrient composition of diets fed to growing steers for Exp. 3

	Corn Residue		Wheat Straw	
Ingredient, % of DM	Treated	Untreated	Treated	Untreated
Treated residue/straw[1]	69	-	69	-
Untreated residue/straw	-	67	-	67
WDGS[2]	30	30	30	30
Supplement	1.0	3.0	1.0	3.0
Fine ground corn	0.8228	1.2388	0.8228	1.2388
Limestone	-	1.5840	-	1.5840
Tallow	0.1000	0.1000	0.1000	0.1000
Trace mineral	0.0500	0.0500	0.0500	0.0500
Vitamin A-D-E	0.1500	0.1500	0.1500	0.1500
Rumensin-90[3]	0.0122	0.0122	0.0122	0.0122
Nutrient Composition, %				
CP	12.62	12.59	13.75	13.56
NDF	64.27	66.60	60.43	64.15
Ca	1.92	0.32	1.45	0.27
P	0.34	0.33	0.44	0.40
Crop Residue				
DM, %	57.6	86.8	49.6	86.7
IVDMD, %[4]	39.6	38.6	43.1	36.1

[1] Treated = Residue treated with 5% CaO (DM basis) after hydration with water to 50% DM at least 7 d prior to feeding, Untreated = no CaO treatment.
[2]WDGS = wet distillers grains plus solubles
[3]Formulated to provide 200 mg per steer/daily.
[4]*in vitro* disappearance of crop residue, 48 hour incubation time.

Table 4. Effects of pelleting and chemical treatment on cattle performance in Exp. 1

	Pelleted		Not Pelleted			*P*-values		
Item	Untreated	$Ca(OH)_2$[1]	Untreated	CaO[2]	SEM	Pellet[3]	T[4]	PxT[5]
Initial BW, kg	313	313	313	313	1	0.49	0.49	0.82
Ending BW, kg	421	434	412	421	5	<0.01	<0.01	0.47
DMI, kg/day	11.9	12.5	9.4	10.1	0.2	<0.01	<0.01	0.58
ADG, kg	1.35	1.50	1.25	1.36	0.06	<0.01	<0.01	0.44
G:F	0.114	0.121	0.132	0.134	0.002	<0.01	0.05	0.18

[1]Treated 50% of the total residue with 6.6% $Ca(OH)_2$, after hydration with water to 65% DM.
[2]Treated with 5% CaO (DM basis) after hydration with water to 50% DM at least 7 d prior to feeding.
[3]Fixed effect of pelleting
[4]Fixed effect of CaO or CaOH treatment
[5]Pellet x CaO or CaOH treatment interaction

Table 5. Effects of MDGS inclusion and alkaline treatment on diet digestibility for Exp. 2[1]

	20 MDGS		40 MDGS			*P*-values		
	Unt	Trt	Unt	Trt	SEM	MDGS[2]	Trt[3]	Int.[4]
DM								
Intake, g	5754	5771	7853	8127	650	<0.01	0.79	0.82
Digestibility, %	49.8	45.6	60.6	58.7	0.1	0.02	0.46	0.79
OM								
Intake, g	5230	5059	7160	7237	602	<0.01	0.92	0.81
Digestibility, %	55.6	52.7	64.0	61.6	0.1	0.05	0.49	0.96
NDF								
Intake, g	3966	3306	4651	4193	398	0.05	0.11	0.77
Digestibility, %	54.9	48.1	56.6	54.3	0.1	0.48	0.37	0.67
Adjusted NDF								
Intake, g[6]	3966	4299	4651	5288	332.8	0.05	0.17	0.60
Digestibility, %[7]	54.5	59.4	56.9	63.2	0.1	0.49	0.19	0.87

[1] Trt = Residue treated with 5% CaO (DM basis) after hydration with water to 50% DM at least 7 d prior to feeding, Unt = no CaO treatment.
[2]Main effect of 20 vs. 40% modified distillers grains plus solubles (MDGS) inclusion.
[3]Main effect of CaO + water vs none.
[4]Interaction of MDGS level and CaO/$Ca(OH)_2$ treatment.
[5]Main effect of calves vs. yearlings.
[6]NDF intakes adjusted so that the NDF value for untreated stalks was also used for treated stalks when intakes were calculated.
[7]Digestibility assuming NDF solubilized is consumed as NDF.

Table 6. Effect of steer age on intakes and diet digestibility for Exp. 2.

	Calves	Yearlings	SEM	Age[1]
DM				
Intake, g	5952	7800	417	<0.01
Digestibility, %	50.5	56.9	0.1	0.14
OM				
Intake, g	5326	7017	386	<0.01
Digestibility, %	55.0	62.0	0.1	0.08
NDF				
Intake, g	3468	4590	255	<0.01
Digestibility, %	50.8	56.2	0.1	0.31

[1]Main effect of calves vs. yearlings.

Table 7. Ruminal pH of steers fed alkaline treated crop residue with modified distillers grains plus solubles.

	20 MDGS		40 MDGS			*P*-values		
Item	Trt	Unt	Trt	Unt	SEM	Trt[2]	Level[3]	TxL[4]
Maximum pH	6.94[b]	7.47[a]	7.04[ab]	6.97[ab]	0.30	0.10	0.56	<0.01
Average pH	6.65[b]	7.13[a]	6.80[ab]	6.70[b]	0.20	0.01	0.56	<0.01
Minimum pH	6.45[b]	6.80[a]	6.54[ab]	6.38[b]	0.13	0.33	0.26	<0.01

[1] Trt = Residue treated with 5% CaO (DM basis) after hydration with water to 50% DM at least 7 d prior to feeding, Unt = no CaO treatment.
[2]Fixed effect of chemical treatment.
[3]Fixed effect of MDGS level.
[4]Interaction of chemical treatment x MDGS level.
[ab]Numbers in the same row lacking a similar superscript differ, $P < 0.10$.

Table 8. Effect of crop residue and alkaline treatment on growing steer performance for Exp. 3

	Corn residue		Wheat straw			*P*-values		
Item	Treated[1]	Untreated	Treated[1]	Untreated	SEM	CaO[1]	Residue[2]	CaO x Residue
Initial BW, kg	331	331	331	330	0.64	0.59	0.43	0.19
Ending BW, kg	384[b]	379[c]	395[a]	382[b]	2.60	<0.01	<0.01	<0.01
DMI, kg/day	7.6	7.1	8.5	7.5	0.4	<0.01	<0.01	0.15
ADG, kg	0.76[b]	0.69[c]	0.92[a]	0.74[bc]	0.04	<0.01	<0.01	<0.01
G:F	0.100	0.097	0.108	0.099	-	0.06	0.07	0.18

[1] Treated = Residue treated with 5% CaO (DM basis) after hydration with water to 50% DM at least 7 d prior to feeding, Untreated = no CaO treatment.

[2]Main effect of CaO + water or none.

[3]Main effect of residue type (corn residue or wheat straw).

[abc]Within a row, means lacking common superscripts differ, when interaction $P < 0.05$.

CHAPTER IV. Optimum Inclusion of Alkaline-Treated Cornstalks and Distillers Grains Fed to Calf-fed Steers

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ABSTRACT

A 180-d finishing study was conducted to identify how varying concentrations of modified distillers grains plus solubles (MDGS) and alkaline treated corn residue (TR) affect performance and carcass characteristics. Crossbred steer calves (n = 378; initial BW = 320 ± 7 kg) were utilized in a 2 x 3 + 1 factorial treatment arrangement. Factors included inclusion rate of MDGS (20% or 40%; DM basis) and TR (10, 20, or 30%; DM basis). In addition, a DRC, 20% MDGS, and 5% untreated stalks control (CON) was fed. There was a distillers inclusion by treated stalks interaction for both carcass adjusted G:F ($P < 0.10$) and G:F based on final live BW ($P < 0.05$). However, no interactions were observed between TR and MDGS inclusion for DMI ($P = 0.47$), ADG ($P = 0.21$), or carcass characteristics ($P > 0.21$). Intakes were not impacted by treatment ($P > 0.18$). Gain decreased linearly ($P < 0.01$) as TR increased within 20% MDGS. However ADG quadratically decreased ($P < 0.01$) when TR was added to the 40% MDGS diets with ADG equivalent between 10 and 20% and decreasing at 30% inclusion. Similar to ADG, G:F decreased linearly ($P < 0.01$) when TR was increased from 10 to 30% in diets with 20% MDGS. However, G:F decreased quadratically ($P < 0.01$) when TR increased in diets with 40% MDGS with equal G:F being observed for the 10 and 20% TR diets then decreasing when TR increased to 30%. Dressing percentage decreased linearly ($P < 0.01$) when TR was included in the 40% MDGS diets and decreased quadratically ($P = 0.05$) when fed with 20% MDGS. A linear decrease in fat depth was observed as TR increased in both 20 and 40% MDGS based diets. Within 20% MDGS, steers fed CON had the greatest ($P < 0.01$) final BW, ADG, and G:F when all TR inclusions were evaluated. These data suggest that 10 or 20% TR can be fed with 40% MDGS included in the diet

without negatively impacting ADG and G:F. However, in if only 20% MDGS is fed, then 10 or less TR should be fed.

Keywords: calcium oxide, corn residue, distillers, finishing

INTRODUCTION

Corn markets are variable and in times of high prices, cattle producers need alternative low cost feed options. An increase in commodity price is often paired with an increase in production (NASS, 2014). For every kilogram of grain produced, there is approximately one kilogram of corn residue produced (Klopfenstein, 1978). Therefore, when corn production is increased, a low cost roughage option becomes more abundant. However, maturity of the corn plant at the time of grain harvest leads to residue digestibility of approximately 50% or less (Klopfenstein, 1978). While corn replacement with corn residue for finishing cattle would be a cheap alternative, dietary NE_g would be dramatically reduced (NRC, 1996) therefore decreasing ADG and G:F (Owens, 2011).

However, feeding value of low quality corn residue can be improved by alkaline treatment with calcium oxide. Klopfenstein (1978) stated that chemical treatment increases the extent of cellulose and hemicellose digestion, while also increasing the rate of cellulose and hemicellulose digestion. Improved digestion can be attributed to the swelling of the forage, therefore allowing microbial attachment (Tarkow and Feist, 1968). Shreck et al. (2013b), observed similar ADG and G:F when 15 percentage units of corn and 5% stalks were replaced with 20% CaO treated corn stover in a diet containing 40% modified distillers grains. In a similar study, Johnson et al. (2013) found that when 20% CaO treated stover replaced 15 percentage units of corn and untreated stover, ADG and G:F were not different. However, in a commercial study completed by Cooper et al.

(2014), cattle fed 35% WDGS and 20% CaO treated corn stover tended to decrease gains and were less efficient than the control cattle. However, in these studies at least 35% modified or wet distillers plus solubles along with treated residue were included in diets.

Due to variable distillers inclusions possible under different economic scenarios, producers need to know whether inclusion of distillers grains plus solubles impacts how alkaline treated stalks perform in finishing diets. Therefore, the objective of this study was to identify the maximum amount of treated forage that can be fed in combination with two inclusions of MDGS without negatively impacting cattle performance and carcass characteristics.

MATERIALS AND METHODS

A 180-d finishing trial was completed using three hundred seventy eight crossbred steers (BW = 320 ± 7 kg). Steers were received as calves at the University of Nebraska beef research facility located at the Agricultural Research and Development Center (Mead, NE) in October, 2012. Upon arrival, steers were individually weighed and identified with three tags, vaccinated with a modified live virus vaccine for protection against IBR, BVD, PI3, respiratory syncytial virus, *mannheimia haemolytica*, and *pasteurella multocida* bacteria (Vista Once, Merck Animal Health, Desoto, KS), an injectable for protection against external parasites (Cydectin Injectable, Boehringer Ingelheim, St. Joseph, MO), and orally drenched for protection against internal parasites (Safe-Guard, Merck Animal Health). Until trial initiation, calves were assigned to pens and received one of two receiving rations for approximately 25 days (Peterson et al., 2014) after initial processing. Following the receiving trial, steers were limit fed a diet containing 50% sweet bran, and 50% alfalfa hay (ALF; DM basis) at 2.0% of BW for 5 d

prior to initiation of the finishing study to minimize gut fill variation (Watson et al., 2013). On d 0 and 1, steers were individually weighed with BW averaged in order to get an accurate initial BW (Stock et al., 1983). On d 1, steers were vaccinated for prevention of *Clostridium chauvoei*, *semticum, novyi,* and *sordellii* and *perfringens* Types C&D (Vision 7, Merck Animal Health), and a booster of modified live IBR, BVD Types I & II, PI3, and BRSV (Vista 5, Merck Animal Health), and were implanted with Revalor-XS (Merck Animal Health, containing 4 mg estradiol and 20 mg trenbolone acetate).

Based on first day weights, steers were separated into two weight blocks, stratified by BW within block, and assigned randomly to pens. Pens were assigned randomly to one of seven treatments, with six pens per treatment and nine steers per pen. There were three replications per block. A generalized randomized block design was used with treatments setup in a 2 x 3 + 1 factorial. Factors were level of modified distillers grains plus solubles (**MDGS;** 20 or 40%) and inclusion of alkaline treated corn stalks (10, 20 or 30%; Table 1) as a replacement for dry-rolled corn (**DRC**) . A control (**CON**) diet was also fed that contained 71% DRC, 20% MDGS, and 5% untreated stalks. Previous in vitro work by Shreck (2013b) treating corn residue with 5% CaO (DM basis) at 50% DM resulted in improved residue digestibility; therefore the same process was utilized for this study. All corn stalk round bales used for this study were harvested from the same field. All stalks were tub ground (Mighty Giant, Jones Manufacturing, Beemer NE) through a 2.54 cm screen, and stored under a roof in a commodity bay. Chemical treatment involved adding CaO (0 to 0.098 cm granular standard quicklime, Mississippi Lime Co., St. Louis, MO), and ground residue hydrated to 50% DM with water addition. Calcium oxide was added at 5% of stalks on a DM basis. Feed trucks dispensed treated

residue into a bunker and were then covered with plastic. This treatment process was completed every two weeks continuously throughout the trial, allowing for residue to be exposed for at least one week prior to feeding. Untreated residues were ground and stored under roof with no added moisture or chemical. Modified distillers grains plus solubles were purchased from a commercial ethanol plant (Green Plains, Central City, NE) and delivered as needed (approximately 1 semi-load/wk). All diets contained 4% dry supplement, which was formulated for 33 mg/kg daily of monensin (Rumensin, Elanco Animal Health, Greenfield, IN) and to provide 90 mg/steer daily of tylosin (Tylan, Elanco Animal Health) with estimate intakes of 10 kg. Calcium oxide (formulated to contain 71% Ca based on molecular weights) replaced limestone in diets containing 20 and 30% alkaline treated stalks. Feedbunks were assessed daily at approximately 0630 am and managed so calves were at ad libitum intake. When refusals were present; orts were removed and dried in a 60°C forced air oven (Model LBB2-21-1, Despatch, Minneapolis, MN) for 48 h to establish DM (AOAC Method 935.29). Feed ingredients were sampled weekly and DM was determined using the same procedure used for orts.

Two to four adaptation diets (treatment dependent) were used to adapt cattle to final diets. Cattle assigned to diets containing 10% TR (with 20% MDGS) and CON were adapted using four adaptation diets where alfalfa was decreased from 37.5% to 27.5% to 17.5% to 7.5% to 0 (DM basis), and were fed their finishing diet on d 28. Pens assigned to the 40% MDGS and 10% TR treatment were adapted after 4 steps (32.5%, 22.5%, 12.5%, and 5% alfalfa; DM basis) and reached their target ration on d 21. Within both 20% and 40% MDGS diets, cattle assigned to 20% TR diets were adapted after 3 steps (27.5%, 17.5%, and 7.5% alfalfa; DM basis), and reached their final diet on d 14. Cattle

assigned to diets containing 30% TR finished adaptation after 2 steps (17.5%, 7.5% alfalfa), and began their final ration on d 14. In each step, alfalfa was replaced with dry rolled corn. Inclusion of crop residue and MDGS was the same in the adaptation diets as in the final experimental diets for each treatment. Steers were fed once daily and allowed ad libitum access to feed and water. All cattle were supplemented with Zilmax (8.36 mg zilpaterol/kg of feed, Merck Animal Health) for 20 d and Zilmax was removed from the feed during the final 3 d for required withdrawal time. Cattle were fed for 180 d (November 15, 2012 to May 13, 2013). Prior to shipment, steers were pen weighed at 1600 h (Norac M2000, Norac Inc. Bloomington, MN), loaded, then transported. All cattle were shipped to a commercial packing plant (Greater Omaha Pack, Omaha, Nebraska), held overnight, and slaughtered the following morning. A 4% shrink was applied to BW to calculate live BW and dressing percentage. Hot carcass weight was collected on the day of harvest and 12^{th} rib fat thickness, LM area, and USDA marbling scores were collected following a 48-h chill. Final BW, ADG, and G:F were calculated using HCW adjusted to a common (63%) dressing percentage. A constant KPH of 2.5% was assumed and used in the USDA yield grade calculation of Boggs et al. (1998). Throughout the trial, two steers were treated for foot rot, four were treated for respiratory disease, one for bloat, and one for a toe abscess. Five steers died while on trial. Cause of death included PEM (20 TR with 20 MDGS), a perforated abomasal ulcer (20 TR with 20 MDGS), bloat and pericarditis (20 TR with 40 MDGS), and one death was undeterminable due to autolysis (10 TR with 20 MDGS).

Performance and carcass data were analyzed as a 2 x 3 + 1 factorial using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.) as a generalized randomized

block design with two blocks and 3 reps/block. Pen served as the experimental unit and BW block was included as a fixed effect. Initially, the 2 x 3 factorial was tested for an interaction. If no significant interaction was observed, main effects of TR inclusion were evaluated. Also, orthogonal linear and quadratic contrasts were used to determine the response curve for alkaline treated forage within MDGS inclusion. If there was an interaction, then orthogonal and linear contrasts of TR within each distillers inclusion were evaluated. The F-test was used to compare all treatments to the control diet. For all analysis, a $P \leq 0.10$ was deemed significant.

RESULTS

Performance

For the 2 x 3 performance portion of the experiment, a quadratic interaction between TR and MDGS inclusion was observed for carcass adjusted G:F ($P < 0.03$; Table 2) and G:F based on final live BW ($P < 0.01$). For carcass adjusted G:F, a linear decrease ($P < 0.01$) was noted within the 20 MDGS treatment diets as TR increased from 10 to 30%. Conversely, within the 40 MDGS inclusion, a quadratic effect was observed ($P < 0.01$) with an evident 14% decrease as TR inclusion increased from 10 and 20% to 30%. Similar results were noted for live G:F with a linear decrease within 20 MDGS diets and a quadratic decrease for 40 MDGS diets ($P < 0.01$). No linear or quadratic interactions were observed for DMI, carcass adjusted final BW ($P > 0.12$), or carcass adjusted ADG ($P > 0.16$). Quadratic decreases were observed as main effects for carcass adjusted final BW ($P < 0.01$) and carcass adjusted ADG ($P < 0.01$) as TR increased within treatments. Dry matter intake was not impacted by increasing TR inclusion ($P > 0.25$). Greater DMI, carcass adjusted final BW, carcass adjusted ADG ($P < 0.01$), and

improved carcass adjusted G:F ($P \leq 0.08$) were observed with 40 MDGS when compared to diets containing 20 MDGS.

Compared to the control, intakes were not impacted by treatment ($P > 0.18$; Table 3) and no differences were observed across different treated stalk inclusion. Carcass adjusted final BW, carcass adjusted ADG, and live G:F at 10 TR with 20 MDGS and 10 or 20 TR with 40 MDGS were comparable to the control diet ($P < 0.01$). However for carcass adjusted G:F, only cattle on the 10 or 20 TR with 40 MDGS showed similarities to the control ($P < 0.01$), which has 5% untreated stalks with 20% MDGS.

Carcass Characteristics

A linear interaction ($P < 0.09$; Table 2) was observed for dressing percentage. For dressing percentage within the 20 MDGS level, a quadratic decrease was observed ($P = 0.05$) while a linear decrease ($P < 0.01$) was noted within 40 MDGS. No linear or quadratic interactions were observed for the remaining carcass characteristics ($P > 0.42$).

When main effects are considered, increasing TR from 10 to 30% resulted in a quadratic decrease ($P < 0.01$) of HCW. Fat thickness generally reflected changes in ADG with cattle that gained less being leaner at slaughter with a linear decrease ($P < 0.01$) as TR increased. For LM area and marbling, quadratic decreases ($P = 0.03$) were observed as TR increased in diets from 10 to 30%. With 40% MDGS inclusion, HCW was increased by 4% ($P < 0.01$), cattle tended to be fatter at slaughter by 11% ($P < 0.01$), and marbling scores were decreased by 3% ($P < 0.01$) when compared to cattle consuming 20% MDGS diets.

When compared to the control, LM area and marbling were not impacted by treatment ($P > 0.18$; Table 3). However, similar characteristics were noted for dressing

percentage between 10 or 20 TR with 40 MDGS and the control ration ($P < 0.01$). Both HCW and 12th rib fat were similar ($P < 0.01$) to the control at 10 TR with 20 MDGS and 10 or 20 TR with 40 MDGS.

DISCUSSION

Overall, improved ADG, G:F, and carcass characteristics were observed in cattle receiving 40 MDGS when compared to 20 MDGS. Improved G:F when MDGS is increased from 20 to 40% is consistent with previous research (Klopfenstein et al., 2008; Bremer et al., 2011; Nuttelman et al., 2010). In a meta-analysis by Bremer et al. (2011), the authors observed a 2% G:F improvement when MDGS was increased from 20 to 40%, in the current study a 5% improvement was observed. However, Bremer et al. (2011) observed similar ADG between 20 and 40% MDGS (1.77 and 1.74 kg/d respectively) while in the current study an 8% increase occurred with increasing MDGS inclusion. Nuttelman et al. (2010) also compared performance of cattle fed 20 and 40% wet, modified, and dried distillers grains and observed an ADG increase of 3% when distillers grains inclusion increased from 20 to 40%. Similar to the current study, Nuttelman et al. (2010) also observed increased HCW and 12th rib fat thickness when distillers grains were increased from 20 to 40%. It is important to note that despite high TR inclusion of the current study, distillers grains results were consistent with previous finishing work. Characteristics of wet and modified distillers grains allow for acceptable performance when low quality roughages are included in finishing rations. The crude protein concentration found in distillers grains makes up for the lack of protein in low quality forages. Specifically, distillers grains contain a high percentage of undegradable intake protein (UIP) allowing for increased intestinal protein absorption (Larson et al.,

1993). Additionally, moisture from wet and modified distillers grains increases diet palatability, helps with mixing, and decreases sorting (Erickson et al., 2010). Also, distillers grains contain fat that is partially protected from rumen degradation, therefore allowing greater total tract fat digestibility (Vander Pol et al., 2009). Benton et al. (2007) evaluated high or low inclusions (2.46 or 4.93% NDF) of varying roughage sources (alfalfa hay, corn silage, or corn stalks) in diets containing 30% WDGS. With each roughage source, DMI and ADG were improved with roughage addition when compared to the 0% roughage control. Significant differences in G:F were not apparent between roughage level and source, illustrating the impact that distillers grains have when included in diets containing low quality roughages.

Similar to the current study Shreck et al. (2012) evaluated corn replacement with 20% TR and 40% WDGS to an 20% untreated corn residue diet, and a control containing 10% untreated roughage and 40% WDGS. The authors observed that the 20% treated residue diet outperformed the 20% untreated residue diet. However similar to the current study, the 20% TR diet maintained similar final BW, ADG, G:F, HCW, and 12th rib fat as the control diet. Comparably, Johnson et al. (2013) tested diets with 20% treated or untreated corn residue with 40% MDGS to a control containing 5% untreated corn residue and 40% MDGS. Similar to the current study and data from Shreck et al. (2012), the authors found that the 20% treated residue diet produced final BW, ADG, and G:F comparable to the control diet. In a separate study by Shreck et al. (2013a), two distillers:treated stalk ratios (3:1 and 2:1) were compared to a 5% untreated stalk and 35% MDGS control diet. Within the 3:1 ratio, increasing forage did not effect G:F ($P \geq$ 0.15). In a commercial study, Cooper et al. (2014) compared a 6% untreated residue and

35% WDGS control diet to a diet containing 20% treated stalks and 35% WDGS. The authors observed decreased final BW, ADG and a 5% decrease in G:F with the CaO treated diet. The current study and previous research indicate that corn replacement with up to 20% CaO treated corn residue in distillers grains based diets improve or maintain G:F when compared to a corn based control diet.

Intakes increase with addition of roughage (Arelovich et al., 2008), especially considering that dietary NDF from roughage can account for up to 92 to 93% of the variation in DMI for finishing cattle on high concentrate rations (Galyean and Defoor, 2003). For the present study, the assumption can be made that control cattle intakes were being regulated chemostatically. However, no differences in intake were noted as roughage content was increased. Bartle et al. (1994) evaluated similar roughage inclusions (10, 20, or 30%; DM basis) supplied by either alfalfa or cottonseed hulls. Dry matter intake was increased by 24% as roughage increased from 10 to 30% ($P < 0.01$). This is most likely due to energy dilution, and the animals attempt to maintain energy intake. In the present study, similar intakes were noted across treatments ($P > 0.18$), however there was a numerical tendency for cattle on the 40 MDGS diets to have greater DMI when compared to cattle on the 20 MDGS diets (including the control). This slight difference is likely attributed to increasing overall palatability and moisture content of the diet (Klopfenstein et al., 2008). In the Bartle et al. (1994) study, despite increased DMI, both ADG and G:F decreased as roughage increased in finishing rations, representing the negative effects of increasing roughage on gains and efficiency (Stock et al., 1990).

It can be concluded that the maintenance of G:F between the control and diets with 10 or 20 stalks and 40 MDGS is most likely due to 1) improved digestibility of the

low quality corn residue, and 2) increased MDGS inclusion. Klopfenstein (1978) stated that the chemical treatment modes of action include: 1) solublization of hemicellulose, 2) increasing the extent of cellulose and hemicellulose digestion, and 3) increasing the rate of cellulose and hemicellulose digestion, leading to an increase in overall digestibility and forage utilization. Another important factor is that treated corn residues are not only replacing corn, but also roughage in the control diet (Shreck, 2013a). Additionally, there is extensive research showing G:F improvement when distillers grains are increased to 40% in diets compared to 20% (Bremer et al., 2010).

From the current study, increasing forage content increased variability of live BW when compared to final weights based on carcass weight adjusted to a common 63% dressing percent. In the current study, as forage increased, dressing percentages decreased. This illustrates the negative impact of increasing forage on dressing percentage, which is caused by gutfill when compared to diets containing large amounts of grain and by-products. Similar results have been observed by Prior et al. (1977) and Bowling et al. (1978) where forage fed cattle exhibited decreased dressing percentage after being harvested at similar live weights when compared to cattle on high concentrate rations.

Feeding steers up to 20% corn stover treated with 5% calcium oxide at 50% DM with 40% MDGS was able to produce similar final BW, ADG, and G:F as well as HCW, dressing percentage, and 12^{th} rib fat when compared to a control diet consisting of 35 fewer DM percentage units of DRC. These differences are most likely due to increased fiber digestibility produced by calcium oxide treatment and distillers grains inclusion.

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Table 1. Diet composition for diets containing 20% or 40% MDGS and 10%, 20% or 30% treated stover. [1,2]

		20 WDGS			40 WDGS		
Item	CON	10	20	30	10	20	30
Ingredient							
Dry rolled corn	71	66	56	46	46	36	26
MDGS	20	20	20	20	40	40	40
Treated Stover	-	10	20	30	10	20	30
Stover	5	-	-	-	-	-	-
Supplement	4	4	4	4	4	4	4
Fine ground corn	1.86	2.68	3.51	3.51	2.68	3.51	3.51
Limestone	1.65	0.83	-	-	0.83	-	-
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Tallow	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Trace mineral	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Vitamin A-D-E	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150	0.0150
Rumensin	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165
Tylan	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102	0.0102
Nutrient Analysis[3]							
CP	13.58	13.35	12.90	12.44	17.99	17.54	17.08
NDF	19.79	22.30	28.18	34.05	26.54	32.41	38.29
Ca	0.06	0.36	0.69	1.02	0.37	0.69	1.02
P	0.40	0.39	0.37	0.36	0.52	0.50	0.48

[1]Values presented on a DM basis.
[2]MDGS = modified distillers grain with solubles.
[3]Dietary nutrient analysis based only on feed ingredients included in the diet.
[4]Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co.
[5]Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, and 3.7 IU of Vitamin E.
[6]Premix contained 330 mg/hd/d of monensin kg-1 (Elanco Animal Health, Greenfield, IN).
[7]Premix contained 90 mg/hd/d of tylosin kg-1 (Elanco Animal Health).

Table 2. Performance of finishing cattle comparing the main effects of 10, 20, or 30% alkaline treated stalks within either 20 or 40% MDGS.[1]
[abcde]From the F-test, means lacking common superscripts, differ $P < 0.05$.

	20 MDGS					40 MDGS						Linear	Quad.	
Item	10	20	30	L[2]	Q[3]	10	20	30	L[2]	Q[3]	SEM	DxT[4]	DxT[5]	Dist.[6]
Carcass Performance														
Initial BW, kg	320	321	321	0.12	0.84	320	320	320	1.00	0.92	1	0.19	0.93	0.56
Final BW, kg[7]	641[bc]	626[cd]	595[e]	<0.01	0.24	653[ab]	660[a]	619[d]	<0.01	<0.01	14	0.43	0.17	<0.01
DMI, kg/d	10.7	10.8	10.5	0.51	0.25	10.8	11.0	11.0	0.34	0.70	0.32	0.26	0.60	<0.01
ADG, kg[8]	1.77[bc]	1.69[cd]	1.51[e]	<0.01	0.23	1.84[ab]	1.88[a]	1.65[d]	<0.01	<0.01	0.07	0.35	0.16	<0.01
G:F	0.166[b]	0.156[c]	0.143[d]	<0.01	0.54	0.170[ab]	0.170[ab]	0.149[d]	<0.01	<0.01	0.002	0.65	0.03	0.08
Live Performance														
Live BW, kg[9]	634[bcd]	625[cde]	612[e]	0.01	0.69	642[ab]	651[a]	624[de]	0.02	0.01	12.64	0.84	0.12	<0.01
Live ADG, kg	1.73[bc]	1.69[cd]	1.61[d]	<0.01	0.70	1.78[ab]	1.83[a]	1.67[cd]	0.01	0.01	0.06	0.78	0.11	<0.01
Live G:F	0.163[a]	0.156[b]	0.153[b]	<0.01	0.48	0.164[a]	0.166[a]	0.152[b]	<0.01	<0.01	0.002	0.54	<0.01	0.04
Carcass Characteristics														
HCW	404[bc]	395[cd]	375[e]	<0.01	0.24	411[ab]	416[a]	390[d]	<0.01	<0.01	9	0.42	0.48	<0.01
Dressing, %[10]	63.7[bc]	63.1[cd]	61.2[e]	<0.01	0.05	64.1[ab]	63.8[ab]	62.5[d]	<0.01	0.11	0.3	0.09	0.79	0.82
LM area, cm^2	90.3	91.6	89.0	0.54	0.23	91.0	93.5	90.5	0.67	0.10	0.18	0.89	0.73	0.12
12th Rib fat, cm	1.35[a]	1.17[b]	0.99[c]	<0.01	0.98	1.50[a]	1.35[a]	1.09[bc]	<0.01	0.45	0.02	0.59	0.57	<0.01
Marbling[11]	488	488	470	0.30	0.53	476	462	463	0.44	0.62	13	0.59	0.57	<0.01

[abcde] From the F-test, means lacking common superscripts, differ $P < 0.05$.
[1]MDGS = modified distillers grains plus solubles.
[2]Main effects of linear response to concentration of treated stalks.
[3]Main effects of quadratic response to concentration of treated stalks.
[4]Linear interaction of distillers grains concentration by alkaline treated stalk concentration.
[5]Quadratic interaction of distillers grains concentration by alkaline treated stalk concentration.
[6]Main effects of 20 vs. 40 MDGS.
[7]Calculated as HCW/common dress (63%).
[8]Calculated from carcass-adjusted final BW.
[9]Pen weight before slaughter shrunk 4%.
[10]Calculated as HCW/Live BW.
[11]400=Small.

Table 3. Performance of finishing cattle comparing the simple effects of 10, 20, or 30% alkaline treated stalks with either 20 or 40% MDGS with the control diet that included 5% untreated stalks and 20% MDGS.[1]

		20 MDGS			40 MDGS				
Item	CON	10	20	30	10	20	30	SEM	F-Test
Carcass Performance									
Initial BW, kg	320	320	321	321	320	320	320	1	0.74
Final BW, kg[2]	655^{ab}	641^{bc}	626^{cd}	595^{e}	653^{ab}	660^{a}	619^{d}	14	<0.01
DMI, kg/d	10.7	10.7	10.8	10.5	10.8	11.0	11.0	0.32	0.18
ADG, kg[3]	1.85^{ab}	1.77^{bc}	1.69^{cd}	1.51^{e}	1.84^{ab}	1.88^{a}	1.65^{d}	0.07	<0.01
G:F	0.173^{a}	0.166^{b}	0.156^{c}	0.143^{d}	0.170^{ab}	0.170^{ab}	0.149^{d}	0.002	<0.01
Live Performance									
Live BW, kg[4]	640^{abc}	634^{bcd}	625^{cde}	612^{e}	642^{ab}	651^{a}	624de	12.64	<0.01
Live ADG, kg	1.77^{ab}	1.73^{bc}	1.69^{cd}	1.61^{d}	1.78^{ab}	1.83^{a}	1.67^{cd}	0.06	<0.01
Live G:F	0.166^{a}	0.163^{a}	0.156^{b}	0.153^{b}	0.164^{a}	0.166^{a}	0.152^{b}	0.002	<0.01
Carcass Characteristics									
HCW	412^{ab}	404^{bc}	395^{cd}	375^{e}	411^{ab}	416^{a}	390^{d}	9	<0.01
Dressing, %[5]	64.4^{a}	63.7^{bc}	63.1^{cd}	61.2^{e}	64.1^{ab}	63.8^{ab}	62.5^{d}	0.3	<0.01
LM area, cm[2]	92.9	90.3	91.6	89.0	91.0	93.5	90.5	0.18	0.02
12th Rib fat, cm	1.47^{a}	1.35^{a}	1.17^{b}	0.99^{c}	1.50^{a}	1.35^{a}	1.09^{bc}	0.02	<0.01
Marbling[6]	459	488	488	470	476	462	463	13	0.81

^{abcde}From the F-test, means lacking common superscripts, differ $P < 0.05$.
[1]MDGS = modified distillers grains plus solubles.
[2]Calculated as HCW/common dress (63%).
[3]Calculated from carcass-adjusted final BW.
[4]Pen weight before slaughter shrunk 4%.
[5]Calculated as HCW/Live BW.
[6]400=Small.