IMPROVING THE USE OF FIBER AND ALTERNATIVE FIBER SOURCES IN BEEF CATTLE DIETS

by

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Six studies were conducted to evaluate the use of different technologies to improve the use of fiber and alternative fiber sources in beef cattle diets. Experiments 1 and 2 evaluated the impact of feeding a complete pelleted feed containing alkaline treated corn stover, dry distillers grains plus solubles, and distillers solubles on total tract digestion and performance of growing cattle. Experiments 3 and 4 evaluated the effects of partially replacing corn with the pellet used in Exp. 1 and 2 on total tract digestion and performance of finishing cattle. The remaining 2 experiments, Exp. 5 and 6, evaluated the impact of treating feeds with a fibrolytic enzyme on *in vitro* and *in vivo* digestibility. In Exp. 1, replacing a traditional growing diet with the complete pelleted feed resulted in similar or improved digestibility depending on the corn stover harvest method. However in Exp. 2, feeding the complete pelleted diet increased DMI and ADG if cattle were fed ad libitum, but decreased G:F in the performance study. In Exp. 3, replacing 25% of corn in a finishing diet containing 40% modified distillers grains plus solubles (MDGS) had no impact on total tract digestion. In Exp. 4, replacing up 30% of corn (DM basis) with the pelleted feed in diets containing 40% MDGS had minimal impact on performance. However, replacing more than 20% of corn (DM basis) in diets containing 20% MDGS caused a decrease in HCW. Feeding an exogenous enzyme showed minimal improvements on *in vitro* DM

digestibility and gas production in Exp. 5. Furthermore, supplementing an exogenous enzyme to cattle on a finishing diet had no impact on *in vivo* digestion in Exp. 6. In conclusion, commercially treating harvested corn residue with CaO and pelleting it with distillers by-products produces a pellet that could be used as a completed pelleted feed in growing diet or a partial corn replaced in finishing diets. However, incorporation of the pellet into diets will depend on its price. In addition, these data do not support the use of exogenous enzymes to improve the digestibility of fibrous feedstuffs in beef cattle diets

DEDICATION

I would like to dedicate this dissertation to my grandma, Madge Hardy. You were such an amazing woman and an inspiration to me. You used to always ask me if I was ever going to be done with school, well grandma, I'm finally done. This one is for you.

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Introduction

Forages are an abundant feed source in beef production systems today. Roughly 80% of the feed inputs in beef production systems come from forages when the production and maintenance inputs of the cow are considered (Watson et al., 2015). Additionally, finishing rations always contain some effective fiber component as it is necessary to maintain regular rumen function (Krause et. al., 2003; Galyean and Defoor, 2003).

Including distillers grains plus solubles in beef cattle diets as either a protein (inclusion level of 15-20%, DM basis) or energy source (inclusion levels >20% DM basis) has become common over the past decade (Klopfenstein et al, 2008). Distillers grains plus solubles typically contain 36% NDF (DM basis), which is three times the amount of fiber in corn (Buckner et al., 2013). Consequently, including distillers grains in cattle diets as either a protein and/or energy source increases the overall fiber content of the diet. In 2006, corn prices began to increase in response to the increasing demand for corn by the ethanol industry (Watson et al., 2015). The increased price of corn caused cattle producers to evaluate alternative feed sources like distillers by-products to reduce the amount of corn in diets.

The elevated corn prices also enticed farmers to convert rangeland to cropland. Wright and Wimberly (2013) estimated that 1.3 million acres of grassland had been converted to soybean or corn fields in the north central region from 2006-2011. Furthermore, 55,000 acres of land had been converted to cropland in Nebraska from

2011-2012 (USDA, 2013). This increase in farm land coupled with increased corn yields has resulted in an increase in the amount of corn residue available for cattle producers to utilize as a feed source (Watson et al., 2015). Research has shown that when chemical treatment is applied to corn residue, residue can also be utilized as a partial replacement for corn (Shreck et al., 2015) in addition to distillers by-products. The utilization of feed sources like treated corn stover and distillers grains to replace corn in diets increases the overall fiber content of growing and finishing diets. Therefore, the purpose of this literature review is to discuss the utilization of distillers grains and corn residue in modern cattle diets. In addition, the review will discuss technologies used to improve the utilization of fiber in cattle diets.

Distillers Grains

The fermentation of cereal grains to produce beverage alcohol has been utilized for centuries. Ethanol was first used to power an engine in 1826, but wasn't used as an octane booster until the 1920s and 1930s. It became very popular during World War II due to shortages in fuel. The predominant cereal grain used in the ethanol industry is corn due to its availability and ability to easily convert to alcohol (Bevil et al. 2008). In addition to corn, grain sorghum, wheat, or barley can be used in the fermentation process (Stock et al., 1999). The fermentation of cereal grains in the dry milling industry produces a by-product known as distillers grains, which is commonly used as a feed source in beef cattle production.

The ethanol industry has grown substantially since the 1900s. In 1999, bio refineries produced roughly 2.3 million metric tons of distillers grains, and increased to 39.0 million metric tons in 2011 (RFA, 2015). There was a drop in production in 2012,

with refineries only producing 34.4 million metric tons of distillers grains. However, production increased the following years, and in 2014 ethanol producers provided 39.0 million metric tons of distillers grains (RFA, 2015).

Due to the removal of the starch within the corn kernel, all other nutrients are concentrated three-fold compared to the corn because corn is 2/3 starch (Stock et al., 1999). Distillers grains offer many feeding options in either a pasture or feedlot setting (Erickson et al., 2007). Distillers grains are an excellent source of protein and energy for growing and finishing cattle. Multiple studies have evaluated the use of distillers grains plus solubles as a partial corn replacement.

Watson et al. (2014) conducted 2 finishing studies to evaluate the effects of replacing a 1:1 blend of dry-rolled corn (DRC) and high-moisture corn (HMC) with 0 to 50% (DM basis) wet distillers grains plus solubles (WDGS) or modified distillers grains plus solubles (MDGS). The authors observed improved gain and efficiency when replacing the blend of DRC and HMC with WDGS or MDGS. The authors noted that gain was maximized when 30% (DM basis) of the DRC:HMC blend was replaced with WDGS. However, NEm, NEg, and efficiency were maximized when 40% of the corn blend was replaced with WDGS. Conversely, gain was maximized when 20% of the corn was replaced with MDGS; though, NEm, NEg, and efficiency were maximized when MDGS replaced 50% of the corn blend. Therefore, the authors concluded that the feeding value of WDGS was dependent on the inclusion level, with values ranging from 121 to 178% the value of corn. The same was determined for the feeding values of MDGS with values ranging from 111 to 125% the value of corn. The feeding value of both types of distillers grains was less at greater inclusions (Watson et al., 2014).

Similarly, Bremer et al. (2008) conducted a meta-analysis of studies replacing DRC or HMC with WDGS. There were 34 studies pooled for this meta-analysis. Only studies that replaced DRC, HMC, or a combination of the two types of corn with WDGS (0% to 50% of diet DM) were included in the analysis. The analysis indicated that WDGS fed between 15 to 40% of the diet DM was 130% the feeding value of corn. In most of the studies, performance and carcass characteristics improved up to 30 to 40% inclusion.

The previously discussed studies have looked at the energy value of distillers grains in corn-based finishing diets. However, there have been studies that evaluated the energy value of distillers grains in forage-based diets. Ahern et al. (2015) compiled data from four experiments that compared DRC, DDGS, and WDGS as energy sources in high forage diets. The authors concluded that WDGS was 137% the value of DRC when fed at 15% of the diet, and 136% the value of corn went fed at 30% of the diet. Furthermore, the authors found no differences in the feeding value of WDGS or DDGS.

Based on these studies we can conclude that distillers grains plus solubles (DDGS, MDGS, or WDGS) have a greater energy value greater than corn. Several authors have speculated as to why distillers grain have a greater feeding value than corn in either forage-based growing rations or corn-based finishing rations. Vander Pol et al. (2009) hypothesized that the improved feeding value of distillers grains are a result of an increase in fat digestibility of the distillers by-products compared to fat within the corn. Others have speculated more OM is being digested in the small intestine rather than in the rumen (Ham et al., 1994; Black and Tribe, 1973). Firkins et al., (1985) suggested that the increased flow of MP to the small intestine improves gains and efficiencies of cattle.

Protein

Diets containing 15-20% of the diet DM or less of distillers grains are typically utilizing the by-product as a protein source (Klopfenstein et al., 2008). Distiller's grains are an excellent protein source for cattle, as they contain approximately 31.7% CP (DM basis; Buckner et al., 2011). Of that 31.7% CP, 63% is rumen undegradable protein (RUP; Lopez et al., 2013). Subsequently, distillers grains are low in RDP, which could impact microbial digestion in the rumen. Rumen undegradable protein (RUP) bypasses the rumen without being degraded by rumen microorganisms. Rumen degradable protein is degraded in the rumen by rumen microorganisms, and utilized as a nitrogen source to synthesize microbial crude protein. Microbial crude protein and RUP contribute to the metabolizable protein (MP) supply that goes to the animal. Excess MP can be recycled back to rumen to supply nitrogen to the rumen microorganism when RDP is deficient. It's been estimated that 19 to 96% of the endogenously produced urea may be recycled back to the rumen to meet RDP requirements (Jenkins et al., 2011). However, the production, excretion, and recycling of endogenous urea is influenced by the composition of the animals diet, intake, and efficiency (Jenkins et al., 2011). Therefore, there have been concerns that the amount of RUP being recycled from diets containing distillers grains as an energy source is not enough to meet the RDP requirements of the rumen microorganisms.

Jenkins et al. (2011) conducted a study to evaluate the effects of supplementing RDP (urea) to cattle consuming diets containing either 10 to 20% (DM basis) DDGS or 25% WDGS in DRC based diets. The authors observed no improvements in animal performance or carcass characteristics when urea was supplemented to cattle consuming

diets containing 10 or 20% (DM basis) DDG. Additionally, Jenkins et al. (2011) observed no improvements in cattle performance or carcass characteristics when cattle were supplemented increasing levels of urea in diets containing 25% (DM basis) WDGS. The authors noted that BUN values were high enough to provide adequate amounts of nitrogen if RDP was limited in diets fed 10-25% distillers grains.

Similar to the study by Jenkins et al. (2011), Stalker et al., (2004) evaluated supplemental RDP (i.e urea) in forage based diets where DDG is included at levels that supply excess MP. The authors supplied 0, 33, 67, 100 or 133% of the NRC predicted RDP deficiency for the basal diet being fed. At the conclusion of the trial, performance data were summarized. The authors observed no differences in performance when cattle were supplemented with urea, which agrees with the data reported by Jenkins et al (2011).

In addition to excess MP supplying endogenous urea to ensure adequate RDP is available for rumen microorganisms, MP can be utilized as an energy source for cattle. A study conducted by Conroy et al. (2016) evaluated the impact of feeding individual components of distillers grains on growing cattle performance. All treatments were compared to a 40% DRC and 50% grass hay based control diet. Similar to previously discussed studies, the authors observed an improvement in ADG and G:F when 40% MDGS was fed in place of DRC. The calculated feeding value of the MDGS was approximately 107% the value of corn, which was lower than the 136% reported by Ahern et al. (2015). However, this is likely due to differences in dietary inclusion. Ahern et al. (2015) calculated the feeding value of WDGS at 30% of the diet DM. Conroy et al. (2016) calculated the feeding value of MDGS at 40% of the diet DM. Growing cattle

performance responded quadratically to increasing inclusion of distillers grains, with the optimum inclusion being 35% (DM basis). Conroy et al. (2016) also noted that 20% corn gluten meal (i.e. isolate protein) was 133% the feeding value of corn, which suggests that protein within the distillers grains plays a critical role in the elevated feeding value of distillers grains.

Fat

Lodge et al., (1997) suggested that the feeding value of distillers grains could be coming from both the protein and fat components in distillers grains. Distillers grains have a relatively large amount of fat. Buckner et al., (2011) evaluated distillers grains samples from 6 different dry milling plants, and reported that the average fat content across the 6 plants was approximately 11.9% (DM basis). Fat provides more energy than any other component (Zinn et al., 1994). Fat that is utilized as an energy source must travel to the small intestine, be packaged into a micelle, and absorbed across the intestinal wall (Russell, 2002). Absorption of fatty acids flowing to the small intestine is dependent on the formation of bile salt micelles (Zinn et al. 2000). Zinn et al. (2000) stated that the more surface area on the micelle, the more digestible the fat will be. Increasing the flow of unsaturated fatty acids to the small intestine helps increase surface area of the micelle; therefore, increasing digestibility and energy utilization by the animal (Zinn et al., 2000). Due to the ruminant animals unique ability to modify fatty acids in the rumen via biohydrogenation (Russell, 2002), increasing unsaturated fatty acid flow to the small intestine can be difficult. Consequently, most of the fatty acids flowing to the duodenum are saturated fatty acids.

Vander Pol et al., (2009) conducted a study to evaluate the effects of feeding WDGS or supplemental corn oil on rumen metabolism. It would be practical to assume that fat within WDGS would be similar to the fat within the corn it is derived from. The authors observed more unsaturated fatty acids flowing to the duodenum in diets containing WDGS than the diets supplemented with corn oil. The increased flow of unsaturated fatty acids in diets containing WDGS is indicative of the fat in distillers grains being somewhat protected from rumen biohydrogenation. In addition to the increased flow of unsaturated fatty acids to the small intestine, the authors observed an improvement in total tract digestibility of fat. As previously stated, unsaturated fats have a greater intestinal digestibility (Zinn et al., 200). Therefore, the improvement in total tract digestibility of fat in diets containing WDGS could be a result of the increased outflow of unsaturated fatty acids to the small intestine. As a result, the increased digestibility of the fat within distillers grains could explain the previously discussed increased feeding value of distillers grains in cattle diets. If the fat is contributing to the feeding value of the distillers grains, any modifications to the fat content of the distillers grains could influence the feeding value.

Over the past few years there have been modifications applied to the production of distillers grains to remove oil from thin stillage and from DDGS (Berger et al., 2010). The removal of oil in the dry milling process produces DDGS that contains approximately 30% less fat and 14% more protein (Berger et al., 2010). As previously discussed, fat could contribute to the improved feeding value of distillers grains in beef cattle diets. Therefore, removal of the fat could reduce the feeding value of the distillers grains.

Jolly et al., (2013) evaluated the effects of feeding normal or de-oiled MDGS in finishing diets. De-oiled MDGS was produced by centrifuging the thin stillage (i.e. solubles) stream prior to adding the solubles to the distillers grains. The authors observed no difference in performance between the normal or de-oiled distillers grains. Additionally, the authors observed improved performance for cattle fed de-oiled distillers grains compared to the corn control. Similarly, a study conducted by Bremer et al., (2014) evaluated the effects of feeding normal or de-oiled MDGS on growing cattle performance. The authors reported no difference in performance between the normal and de-oiled distillers grains. These results suggest that the modification of the dry milling process by centrifuging thing stillage is not impacting the feeding value of the distillers grains. Furthermore, it suggests that the fat removed via centrifugation of the solubles stream contributes a small amount, if any, to the overall feeding value of the distillers grains. However, different results have been observed when more extensive fat removal is used to extract fat from the germ.

Roughages in diets containing distillers grains

Roughages are typically included in finishing diets to increase DMI and ADG while optimizing feed efficiency. In addition to optimizing performance, forages are included in rations to circumvent acidosis (Galyean and Defoor, 2003). As previously stated, starch is removed when distillers grains are produced. Consequently, NDF is increased 3 fold within the distillers grains. Therefore, feeding high levels of distillers grains in place of corn results in a reduction in dietary starch, which could potentially reduce incidents of acidosis (Klopfenstein et al. 2008).

A study by Felix et al. (2012) evaluated the effects of feeding increasing levels of DDGS on ruminal pH. The authors fed 0, 20, 40, and 60% (DM basis) distillers grains to finishing cattle. As DDGS increased in concentration, DRC was decreased. All treatments contained 15% corn silage. The authors observed that the cattle fed diets containing 40 and 60% DDGS had a lower ruminal pH 3 h post-feeding than cattle fed diets containing no distillers grains. Furthermore, diets containing 40 and 60% DDGS maintained a lower ruminal pH until ~13 h post-feeding. The results from this study suggest that even though distillers grains provide more dietary NDF than feeding corn, the NDF within the distillers grains may not be effective at controlling rumen pH. Consequently, completely eliminating a roughage source in diets containing high levels of distillers grains may not be ideal for the animal. Controlling drops in ruminal pH is essential for managing acidosis. Completely eliminating a roughage source from the diet increases the risk of acidosis, which can reduce the animal's overall performance.

May et al. (2010) conducted a finishing trial to determine if the concentration of corn silage could be reduced from 15 to 5% when DDGS were included in the diet. Three diets were fed in this study. The first diet consisted of 75.3% steam flaked corn (SFC), 14.8% corn silage, and 4.3% soybean meal. The second diet consisted of 55.6% SFC, 14.9% corn silage, and 24.7% DDGS. The remaining diet consisted of 65.4% DDGS, 4.9% corn silage, and 24.7% DDGS. The authors observed no differences in G:F, ADG, DMI, FBW, or carcass characteristics between the three treatments. A similar study was conducted by Benton et al. (2015).

Benton et al. (2015) evaluated different roughage types and levels in diets containing WDGS to determine if roughages could be exchanged on an equal NDF basis

in finishing diets. Dietary treatments consisted of a control that contained no roughage compared to diets that contained either alfalfa hay, corn silage, or corn stalks at two different levels. Alfalfa was included at either 4 (low) or 8% (standard) of the diet DM. Corn silage (6.14 or 12.26%) and corn stalks (3.04 or 6.08%) were included in diets at concentrations that provide the same amount of NDF as the diets that contained either 4 or 8% alfalfa. The authors observed no difference in G:F between the 7 dietary treatments. However, they did observed a difference in ADG with cattle consuming diets that contained either 3.04 or 6.08% corn stalks having the greatest ADG and cattle consuming the control diet with no roughage having the least. Furthermore, the authors observed that feeding a lower concentration of corn stalks resulted in an improvement in DMI and ADG over cattle fed a lesser concentration of alfalfa hay. However, similar ADG and DMI was observed between cattle fed the low concentration of corn stalks and the standard concentration of alfalfa hay (Benton et al. 2015).

In addition to the finishing performance study, Benton et al. (2015) also conducted a digestion study to evaluate the effects of feeding either alfalfa hay or corn stalks at 2 different levels (low or standard) on total tract digestion of a corn-based finishing diet. A control diet consisting of 65% DRC:HMC blend (50:50), 30% WDGS, and 5% supplement was included. Two dietary treatments replaced either 4 (low) or 8% (standard) of the corn blend with alfalfa hay. The remaining two treatments replaced either 3.04 (low) or 6.08% (standard) of the corn blend with corn stalks. The authors observed a linear decrease in total tract OM digestibility as the concentration of roughage increased. There were no differences in DM, OM, or CP digestibilities between diets

containing either alfalfa or corn stalks. Average ruminal pH linearly increased as roughage inclusion increased, which would be expected.

These data suggest that forages can be replaced on an equal NDF basis in diets containing distillers grains. Even though the NDF from distillers grains does not do a good job of managing ruminal pH, feeding WDGS (~35% DM) or MDGS (~50% DM) supplies moisture to the diet, which could help reduce sorting and improve palatability of higher forage diets. In addition, the greater amounts of protein in the distillers grains (DDGS, MDGS, or WDGS) provide cattle producers more flexibility to feed lower quality forages (i.e. corn residue) that do not supply much protein to the diet (Klopfenstein et al. 2008).

Forage

Forages are a highly utilized feed source in beef production systems. They account for roughly 80% of the feed inputs in beef production systems when the production and maintenance requirements of the cow are considered (Watson et al., 2015). The energy that is acquired from these forages comes from the fermentation of the plant cell wall by the microorganism within the rumen (Beauchemin et al., 2003a; Russel, 2002; Wilson, 1993). The ability of cattle to have productive functions (i.e. milk production or weight gain) when consuming forages is highly influenced by the animals ability to consume enough forage, as well as digest the cell wall of the forages they are consuming (Wilson, 1993). The ability of the rumen microorganism to adequately digest forage is influenced by the structure of the plant cell wall, as well as the rate at which the masticated forage samples pass through the rumen (Wilson, 1993).

Cell Wall Development