Use of Corn Co-Products in Beef Cattle Diets

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Introduction

The ethanol industry has expanded at an amazing rate since the turn of the century. From 2000 to 2011, the US ethanol industry grew from 1.6 billion gallons to 13.9 billion gallons of ethanol produced (Renewable Fuels Association, 2013a). The renewable fuels standard mandates that should there be 20.5 billion gallons of ethanol produced annually in the US by 2015 (Renewable Fuels Association, 2013b) with no more than 15 billion coming from traditional dry milling of corn. The byproduct of ethanol production from fermentation of corn starch (distillers grains; **DG**) have become an important livestock feed because ethanol production now uses nearly 30% of US corn production (National Corn Growers Association, 2012). The nutrient composition of DG may make them a good fit in high forage diets or as a supplement to grazing cattle because they provide protein, energy, and minerals as well as serve as a forage substitute. However, producers considering using these byproducts must be aware of specific risks associated with their use that require special attention, but can be easily managed. Specifically, high sulfur levels may cause polioencephalomalacia or potentially tie up other minerals required by the animal.

Byproducts of Dry Milling

Distillers grains (**DG**) are a byproduct of the dry milling industry. The dry milling process is described elsewhere (Stock et al., 1999), but consists of converting starch from cereal grains into an alcohol through fermentation by yeast. After removal of the alcohol by distillation, the remaining residue, called whole stillage, may be centrifuged or pressed to separate course particles from fine particles and liquid. The course particles are DG and may be fed as wet DG or dry DG (**DDG**), which may affect animal performance (Ham et al., 1994). The fine particles and liquid is called thin stillage, is often evaporated to condensed distillers solubles, and may be marketed separately or a portion may be added back to the DG. Thus, there are a variety of products marketed under the name of DG and there compositions are dependent upon the amount of solubles added back to the DG and other processes of the plant in which the DG are produced. This can lead to substantial variability in the nutrient composition of DG by plants (Table 1; Holt and Pritchard, 2004; Spiehs et al., 2002). However, some generalizations can be made. By weight, roughly one third of the original grain dry matter (**DM**) is converted to ethanol, another third is lost as carbon-dioxide, and one third remains as DG. Therefore, the nutrient composition of DG is approximately three times the nutrients found in the cereal grain from which it was produced.

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Distillers Grain as a Source of Protein and Energy

The nutrient composition of DDG may make them a good fit in high-forage diets or as a supplement to grazing cattle. One potential advantage to using DDG in forage diets is that most of the starch has been removed. Negative associative effects of starch on fiber digestion have long been noted and some have suggested supplementing highly digestible fiber as a means of providing energy without negatively affecting forage digestion (Horn and McCollum, 1987). Using DDG may allow for energy supplementation without decreasing forage digestibility. Griffin et al. (2012) summarized 13 pasture grazing studies and seven confinement-fed studies that supplemented varying amounts of DG to growing cattle. In pasture supplementation studies, each 1% BW supplementation increased average daily gain (**ADG**) by 0.69 lb (i.e. a slope of 0.69) when supplement was provided up to 1.2% BW. The response in confinement situations was quadratic with diminishing returns with increasing amounts of DG supplementation. The response to improved ADG due to DDG supplementation appears to be somewhat consistent with high-quality forages. We supplemented DDG to 600-lb heifers grazing summer range in the Texas Panhandle. Heifers were supplemented three times weekly at a level that was equivalent to 0.5% BW per day. Supplementation of DG resulted in a 14% improvement in ADG and a slope of 0.56 (MacDonald, unpublished data), comparable to the slope of 0.69 in the summary by Griffin et al. (2012). The response to DDG supplementation is likely due to providing a combination of protein and energy. Distillers grains are a good source of undegradable intake protein (**UIP**). They contain approximately 30% of CP, of which 54% (Firkins et al., 1984) to 66% (Ham et al., 1994) bypasses rumen degradation which may improve the efficiency of protein use in high-fiber diets (Horn and Beeson, 1969; Waller et al., 1980; DeHaan et al., 1982). In addition to providing protein, the fat in DG can serve as an energy source. It is difficult to separate effects of DG on animal performance due to protein or energy. We previously supplemented similar amounts of UIP from DDG or corn gluten meal to heifers grazing high quality bromegrass pastures (Figure 1; MacDonald et al., 2007). The gains for cattle supplemented with corn gluten meal were 39% of those supplemented with DDG across three levels of supplementation. Therefore, the response to DDG was not solely due to meeting a UIP deficiency. A third supplementation strategy in this study was to supplement corn oil equivalent to the amount of fat found in distillers grains (data not shown). There was no performance response to supplementing corn oil demonstrating that energy was not the first limiting nutrient for these heifers. As one might expect, there appears to be an additive effect of supplying protein and energy together in one supplement. A recent unpublished analysis by our group comparing the energy value of DG to corn in forage diets fed to confined calves suggests DG has an energy value of 137% and 136% the value of corn when fed at 15 and 30% of the diet, respectively.

As may be expected, the response to DG supplementation to low-quality forage diets appears greater than to high-quality forage diets. However, the response curve is also strikingly consistent across forage types. Steer calves grazing dormant native range were provided DDG thrice weekly at levels equivalent to 0, 0.25, 0.50, or 0.75% BW per day (Jenkins et al., 2009; Figure 2). We observed a large quadratic improvement in ADG across the three levels of supplementation. Steers receiving no supplement gained 0.59 lb/day whereas steers receiving the highest level of supplement gained 1.75 lb/d. Similarly, Gustad et al. (2006) provided DG supplementation from 0.29% to 1.27% BW to steers grazing corn residue and also observed a quadratic increase in ADG. After correcting for the intercept, the response curves of Jenkins et al. (2009) and Gustad et al. (2006) are nearly identical.

Fat as an energy source in DG may be especially advantageous to cow/calf producers. Proper nutrition to first-calf heifers is especially important because the heifers are still growing. During the last trimester of pregnancy, heifers may not be able to physically consume enough feed to meet their nutrient requirements as well as the requirements of the fetus. Therefore, supplementing an energy dense component to the diet may be beneficial. Distillers grains have been shown to give greater weight gains than soybean hulls in pregnant heifer diets fed at 40% of dietary DM in the last trimester of pregnancy without any effect on body condition score (BCS) and without causing calving difficulties (Engel et al., 2005). Fat may also be advantageous for improving conception rates. Smith et al. (2001) supplemented cows grazing native range with equal amounts of CP from DDG or alfalfa hay with and without cull beans at a level which provided half of the CP. When DDG was supplemented alone, a greater percentage of cows were cycling prior to estrus synchronization compared to when DDG was supplemented with cull beans. It is possible that this response is related to the fat in DDG because plant oils are known to affect ovarian follicular growth, luteal function, and postpartum reproductive performance independent of increased energy intake (Williams and Stanko, 1999). However, cows supplemented with only DDG lost more body condition compared to cows receiving other supplements. Cattle consuming low-quality forages may be limited by a degradable intake protein (**DIP**) deficiency rather than a metabolizable protein deficiency. Therefore, providing UIP which bypasses rumen degradation may not elicit a performance response if DIP is deficient. Therefore, the authors suggested that the greater loss of body condition score due to DDG supplementation compared to alfalfa and cull bean supplementation was due to the high UIP content of DDG that did not meet the DIP deficiency.

To determine if DDG could meet a DIP deficiency, Stalker et al. (2004; Table 2) provided urea at a level that met the predicted DIP deficiency to heifers consuming a low-quality hay supplemented with 3 lb of DDG. Two pieces of evidence from this study suggest the DDG met the DIP deficiency. Animals that are deficient in DIP will experience a reduced rate of fiber digestibility, which slows passage of fiber out of the rumen. This results in reduced animal performance and reduced dry matter intake. No differences in animal performance or dry matter intake were detected. Also, a DIP deficiency will reduce microbial growth in the rumen which should subsequently lead to reduced microbial crude protein flow out of the rumen. Researchers in this study used the ratio of allantoin to creatinine as an indicator of microbial crude protein flow. An increase in the ratio of allantoin to creatinine would indicate an increase in microbial flow. No differences in this ratio were detected. These data indicate that DDG can be used to meet a DIP deficiency while providing metabolizable protein from UIP and energy. Physiologically, this is achievable through recycling of nitrogen to the rumen. It is unclear why cows receiving DDG lost more body condition compared to other treatments in the study by Smith et al. (2001), but it may not be due to a DIP deficiency.

Forage Intake and Supplementation Frequency

Effects of supplementation with DDG may include improved animal performance and/or reduced forage intake (i.e. forage substitution). Forage substitution may allow for additional animal units to graze a fixed land base and thus is an important consideration when considering a forage supplement. Morris et al. (2005) provided 1.5, 3.0, 4.5, or 6.0 lb of DDG to heifers consuming either high-quality (alfalfa and sorghum silage) or low quality (bromegrass hay) forage. The efficiency of supplementation (pounds of additional gain per pound of supplement) was greater for the low-quality forage than for the high-quality forage diet (data not shown). However, the effects of DDG supplementation on forage intake (Figure 3) were consistent across forage qualities. The slope of the line for both high and low quality forage was approximately 0.40 suggesting every pound of DDG replaces 0.40 lb of forage. More recently, Gillespie et al. (2012) adjusted grazing pressure by assuming DG supplementation at the level of 0.6% of BW replaced 17% of forage intake. No differences in post-grazing forage residues were observed. Estimated reductions in forage intake are now accurate enough to provide recommendations for changing stocking rate when supplementing DG.

Producers providing supplements to grazing cattle will often supplement several times per week, but not daily. To determine if animal performance is similar when cattle are supplemented with DDG daily or multiple times per week, Stalker et al. (2005; Table 3) supplemented heifers consuming low quality grass hay with the equivalent of 3 lb of DM DDG per day. Heifers were provided supplement either 3 times or 6 times per week. Heifers supplemented 6 times per week had greater ADG compared to those supplemented e times per week. This difference in animal performance due to alternate day supplementation has also been reported by Loy et al. (2003) who compared feeding DDG or dry-rolled corn either daily or on alternate days. Cattle supplemented on alternate days consumed less hay on average compared to cattle supplemented daily. Data from a subsequent metabolism study (Loy et al., 2004) substantiates this forage intake response and indicates the effects on forage intake due to alternate day supplementation are independent of negative effects on rumen metabolism. Producers must determine if the added performance from daily supplementation compared to supplementation several times weekly is profitable when added costs and management are considered. Alternatively, if reduced forage intake were desirable, such as in a drought situation, alternate day supplementation may prove beneficial.

Mineral Considerations

Supplementation strategies are often developed to correct a deficiency; phosphorus is thought to be the most deficient nutrient in the world for grazing livestock (Greene, 1999). The phosphorus content of DDG ranges from 0.70% to 1.00% of DM

(Spiehs et al., 2002). Therefore, supplementation strategies which utilize DG may be able to concurrently reduce the need for phosphorus supplementation for grazing cattle.

One issue that requires special attention for producers considering the use of DG is the level of sulfur it contains. High sulfur levels are associated with polioencephalomalacia (**PEM**; Gould et al., 1991) due to the production of hydrogen sulfide gas in the rumen. Hydrogen sulfide gas is produced because sulfur can be reduced to hydrogen sulfide, thereby providing a hydrogen sink in the rumen. The sulfur content of DDG can range from 0.33 to 0.74% (Spiehs et al., 2002; Table 1). Since corn grain contains approximately 0.14% sulfur (NRC, 1996), the sulfur concentration in the DG above is approximately 0.40%. Presumably, this high S concentration is the result of addition of sulfuric acid during the dry milling process. The maximum tolerable level of sulfur is 0.40% of dietary DM (NRC, 1996). Yet nutritionists in the field commonly feed diets containing DG at levels that exceed 0.40% total dietary sulfur without noticeable PEM. Sarturi et al. (2013) recognized that a portion of the sulfur contained in DG is associated with sulfur containing amino acids. Because DG is also high in UIP, a portion of these sulfur containing amino acids may not be available to the rumen microbes and therefore may not contribute to the production of hydrogen sulfide. The concept of rumen available sulfur (**RAS**) explained 65% of the variation in ruminal hydrogen sulfide production compared to 29% of the variation being explained by total dietary sulfur (Sarturi et al., 2013). Therefore, producers need to be aware of all sulfur sources available to their cattle, including mineral supplement, other feedstuffs, and water. Anecdotal evidence of sulfur toxicity is often associated with cases where producers combined byproducts of the corn milling industries such as DG, condensed distillers solubles, steep liquor, or wet or dry corn gluten feed not realizing that all of these byproducts are potentially high in RAS. Other cases of sulfur toxicity have been reported in cases where producers provided one or more of these byproducts without testing their water source, which may be high in RAS. The issue of sulfur toxicity is relatively easy to manage through testing of feedstuffs and water sources. The cost of testing for sulfur is relatively inexpensive relative to the risk of animal loss.

Conclusions

The opportunity to use DG in high-forage diets has been a tremendous asset to producers located in areas where DG are readily available. Distillers grains provides highly digestible fiber, protein, and fat which increases the performance of cattle consuming high-forage diets. The removal of starch during ethanol production may reduce the negative associative effects on forage digestibility associated with cereal grain supplementation. The protein in DG appears to meet the DIP deficiency associated with intake of low-quality forages. Forage intake is reduced when DDG is supplemented, and to a greater extent when the supplement is provided several times per week rather than daily. However, animal performance may also be reduced when supplemented several times a week rather than daily. Concerns with PEM are more easily managed when using the RAS concept instead of total dietary sulfur.

Although we have a great deal of information to provide recommendations about utilizing DG in high-forage diets, more information will likely be needed in the future. Specifically, three changes in the dynamics of renewable fuels will change the products that will be available to us in the future. First, ethanol plants have begun to remove a portion of the fat from the solubles stream and they are selling the oil for biodiesel production. Second, ethanol produced from sorghum grain has been awarded the classification of an advanced biofuel. Therefore, more DG resulting from fermentation of sorghum will likely be available. Finally, cellulosic ethanol production is being scaled up from pilot plants to production-scale plants. The fiber in DG will be an attractive feedstock for cellulosic ethanol production.

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Table 1. Average nutrient values reported for distillers grains from NRC and range of nutrient values across several plants as reported in two studies[a].

Item	NRC[b]	Holt and Pritchard[c]	Spiehs et al.[d]
DM	91.0	89.4-90.9	87.2-90.2
CP	29.5	30.7-33.2	28.7-31.6
Crude Fat	10.3	10.3-14.2	10.2-11.7
NDF	46.0	37.3-48.9	36.7-49.1
Ca	0.32	NR[e]	0.03-0.13
P	0.83	0.66-0.78	0.70-0.99
K	1.07	0.76-1.07	0.69-1.06
Mg	0.33	0.26-0.33	0.25-0.37
S	0.40	0.37-0.69	0.33-0.74

[a]All values are expressed as a percentage on a DM basis.
[b]Taken from: NRC (1996).
[c]Adapted from: Holt and Pritchard (2004).
[d]Adapted from: Spiehs et al. (2002).
[e]Not reported.

Table 2. Performance and allantoin:creatinine ratio in urine of heifers fed diets where 0 or 100% of the NRC predicted degradable intake protein requirement was met with supplemental urea. Adapted from Stalker et al. (2004)

Item	0	100	SEM	P-value
Initial BW, lb	452	449	1	0.10
Final BW, lb	579	585	4	0.38
Daily gain, lb	1.53	1.63	0.05	0.17
Total DM intake, lb/d	11.9	11.6	0.50	0.76
Feed:gain	9.8	9.1	0.50	0.37
Allantoin:creatinine	0.89	0.89	0.04	0.98

Table 3. Performance of heifers fed the daily equivalent of 3 lb (DM) of dried distillers grains either 3 (3×) or 6 (6×) times per week. Adapted from Stalker et al. (2005)

Item	3x	6x	SEM	P-value
Initial BW, lb	426	424	1.22	0.42
Final BW, lb	559	571	1.93	0.005
Daily gain, lb	1.58	1.74	0.031	0.01

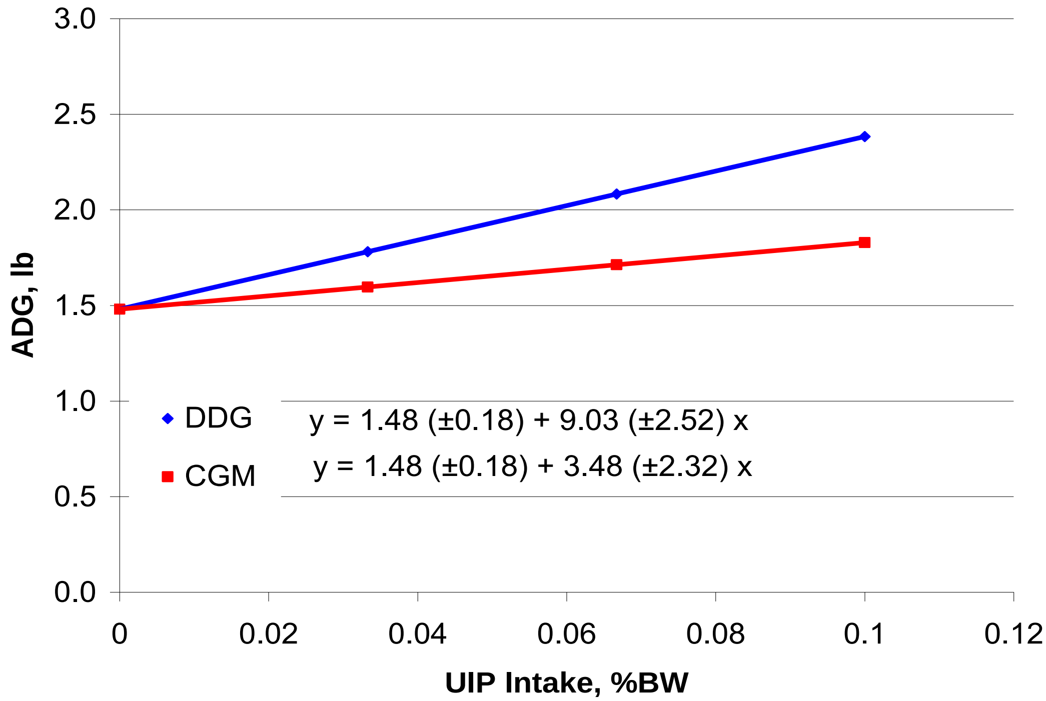

Figure 1. Effect of undegradable intake protein (UIP) intake from dry distillers grains (DDG) or corn gluten meal (CGM) on ADG. DDG slope > 0 (P<0.01). CGM slope > 0 (P=0.14). DDG slope > CGM slope (P=0.10). From MacDonald et al. (2007).

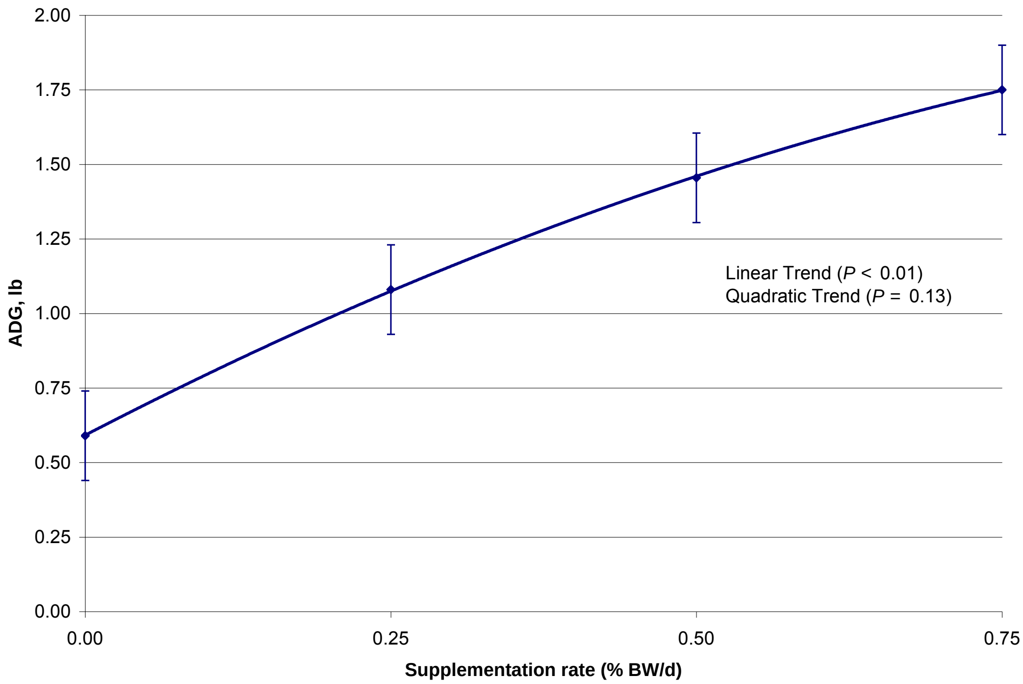

Figure 2. Effects of dry distillers grains supplementation on ADG of calves grazing dormant range (Jenkins et al., 2009).

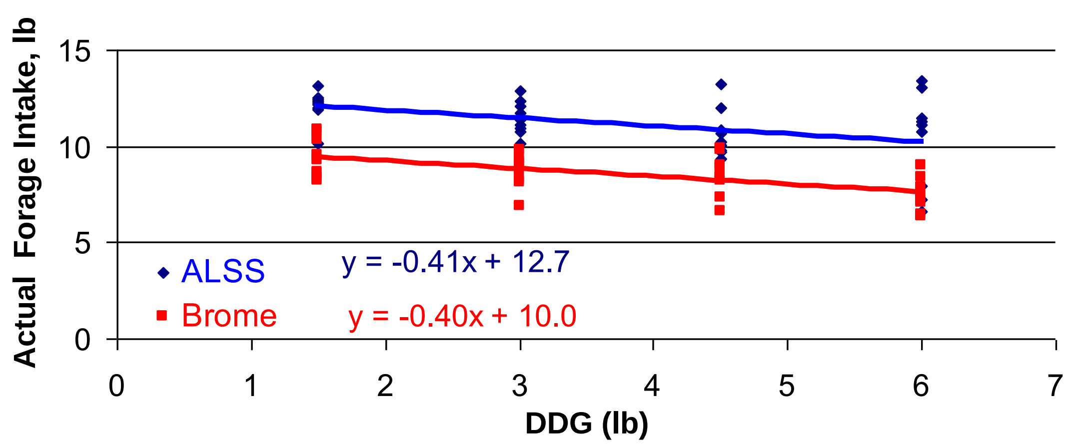

Figure 3. Effects of dry distillers grains (DDG) supplementation on forage intake for heifer calves consuming low quality brome grass hay (Brome) or high quality alfalfa and sorghum silage (ALSS). Adapted from Morris et al. (2005).

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