# Feeding Corn Milling Co-Products to Dairy and Beef Cattle.

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## Introduction

The production of ethanol from corn grain has become an effective strategy to produce high quality and clean liquid transportation fuels. In fact, the growth of the U.S ethanol industry has provided an economic stimulus for U.S.-based agriculture. The feed industry plays an integral role in the ethanol production industry. For example, the primary product of the dry milling production process is ethanol; but approximately one-third of the total dry matter is recovered in the form of co-products. The supply of these co-products continues to grow at a rapid rate. As a result co-products are becoming an increasingly available feedstuff that are usually an extremely cost effective feed ingredient for dairy and feedlot cattle. Two primary types of milling processes currently exist, namely wet and dry milling and these result in quite different feed products.

## Corn Milling Process and Associated Co-Products

*Wet Milling*

The wet milling process is the most complex of the two because the corn kernel is partitioned into several components to facilitate high value marketing. For example, the oil is extracted and sold and the corn gluten meal that contains a large amount of bypass protein, commonly marketed to the dairy, poultry, or pet industries. Wet milling is a process that requires use of high quality (No. 2 or better) corn that results in numerous products that are produced for primarily human use. During this process (Figure 1), corn is “steeped” and the kernel components are separated into corn bran, starch, corn gluten meal (protein), germ, and soluble components. Wet corn gluten feed (**CGF**) usually consists of corn bran and steep, with germ meal added if the plant possesses the capabilities. Wet corn gluten feed can vary depending on the plant capabilities. Steep liquor contains more energy than corn bran or germ meal as well as protein (Scott et al., 1997). Therefore, plants that apply more steep to corn bran or germ meal will produce wet CGF that is higher in CP and energy. Wet CGF contains 16 to 25% CP, with a rumen undegradable protein (**RUP**) value of approximately 24-30 % CP (NRC, 2001). During wet milling, corn gluten meal is removed and marketed in higher value markets. Corn gluten meal *should not* be confused with CGF, as corn gluten meal contains approximately 60-65% CP and a RUP value of approximately 64-75 % CP (NRC, 2001). Distinct differences exist for wet CGF, even within companies, due to plant-to-plant variation.

*Dry Milling*

In the dry milling industry produces the following feed products; distillers grains, distillers grains + solubles, and distillers solubles. Depending on the plant, and whether it is producing wet or dry feed, the proportion of distillers grains and distillers solubles that are mixed together may vary. However, our current estimates are that wet distillers grains + solubles are approximately 65% distillers grains and 35% distillers solubles (DM basis). Distillers grains (+ solubles) will hereby be referred to as either wet distillers grains (**WDG**) or dry distillers grains (**DDG**) and our assumption is that both contain some solubles. The dry milling process (Figure 2) is relatively simple. Specifically corn (or possibly some other starch sources) is ground, fermented, and the starch converted to ethanol and $CO_2$. Approximately 1/3 of the DM remains as the feed product following starch fermentation. As a result, all the nutrients are concentrated 3-fold because most grains contain approximately 2/3 starch. For example, if corn is 4% oil, the WDG or DDG will contain approximately 12% oil.

## Nutrient Composition of Milling Co-Products

### *Nutrient Variation*

Recent investigations conducted at the University of Minnesota (Knott et al., 2004) has demonstrated that there may be a high degree of variation in the nutrient content of co-products, such as distiller's grains, both within and across production plants. For example, these investigators demonstrated that the crude protein level in distillers grains may range from 25 - 35%, with variation also observed in fat (10-12%), NDF (8-10) and phosphorus (0.8-1%). These investigators note that one of the greatest sources of nutrient variation for DDG depends on the amount of solubles that were added to the grains. Along with the concentration of CP, the availability of these nutrients may also vary. Hence researches are beginning to direct their attention towards creating practical methods for controlling this variation. Research from The Ohio State University (Weiss, 2004) suggests that routine feed sampling is essential. Because it may be difficult and time consuming to sample and formulate rations based on lab results of individual loads, numerous load samples should be collected and analyzed over time. This will allow for estimation of the mean values and also the variation of these estimates. Consequently, it becomes possible to protect against underfeeding a nutrient such as protein by feeding an anticipated mean value of the feed.

## Corn Milling Co-products and Cattle Performance

### *Distillers Grains and Feedlot Performance*

Experiments evaluating the use of wet distillers coproducts in ruminant diets are available (DeHaan et al, 1982; Farlin, 1981; Firkins et al., 1985; Fanning et al., 1999; Larson et al., 1993; Trenkle, 1997a; Trenkle, 1997b; Vander Pol et al., 2005a). In the experiments with finishing cattle, the replacement of corn grain with wet distillers coproduct consistently improved feed efficiency. Figure 3 summarizes these studies conducted on wet distillers grains with energy value expressed relative to corn. The energy value is consistently higher than corn. These experiments suggest a 15 to 25% improvement in feed efficiency when 30 to 40% of the corn grain is replaced with wet distillers coproduct. The energy value at medium levels (12 to 28%, average of 17% of diet DM) is approximately 140 to 150% the energy of corn. When higher levels are used (average of 40%), the energy was 130% that of corn. The optimum level for feedlot producers is 30 to 40% of diet DM when plants are within 30 miles of the ethanol plant. As the distance increases from the plant to the feedlot, the optimum inclusion of WDG decreases to 20 to 30%. This comparison suggests that more WDG can be fed; however, the optimum inclusion is dependent on more than just the energy value of WDG. Factors such as price, cattle performance, distance from the plant, and corn price influence the economic optimum inclusion amount.

The evolving ethanol industry is continually striving to maximize ethanol production efficiency. Changes associated with this progress will provide innovative new byproduct feeds for producers to utilize that may be quite different nutritionally when fed to cattle. One example of a new byproduct feed is Dakota Bran Cake. Bran cake is a distillers byproduct feed produced as primarily corn bran plus distillers solubles produced from a hybrid wet and dry milling process. On a DM basis, bran cake contains less protein than wet DGS and wet CGF, similar NDF to both feeds and similar to slightly less fat content as wet DGS. A study by Bremer et al., (2005) evaluated Dakota Bran Cake inclusion up to 45% DM by comparing 0, 15, 30, and 45% of diet DM. Results indicated improved final weight, ADG, DMI and F:G compared to feeding a blend of high-moisture and dry-rolled corn, suggesting this specific feed has 100 – 108% of the energy value of corn. Dakota Bran Cake is only one example of how new ethanol industry byproducts will feed relative to traditional finishing rations. Each new byproduct feed needs to be analyzed individually for correct feeding value. Changes to plant production goals and production efficiency have a significant impact on the feeding value of byproducts produced.

*Corn Gluten Feed and Feedlot Performance*

For a more complete review of the wet milling process, the reader is referred to Blanchard (1992). Dry corn gluten feed contains less energy than wet corn gluten feed (Ham et al., 1995) when fed at high levels in finishing diets. Distinct differences exist for wet CGF, even within companies, due to plant-to-plant variation. Stock et al., (1999) divided wet CGF into 2 main categories, depending on the ratio of steep to bran. Because of differences in the amount of steep added, wet CGF has approximately 100 to 108% the energy value of dry-rolled corn when fed at levels of 20 to 60% of diet DM (Stock et al., 1999). Higher energy (and protein) is associated with increases in steep added in wet CGF.

*Distillers Grains and Lactational Performance*

In published studies evaluating DDG as a protein supplement, milk production was observed to either be unaffected (Clark and Armentano, 1993; Owen and Larson, 1991) or increased (Powers et al., 1995; Nichols et al., 1998). Because DDG may contain as much as 13% ether extract (an estimate of crude fat), the high level of fat is one factor believed that may affect milk fat synthesis and as a result limit the inclusion of DDG into dairy diets. This effect was not observed by Leonardi et al. (2005) who evaluated the effects of increasing levels (up to 15%) of DDG and the addition corn oil to the control diet. These investigators observed an increase in milk and protein yield, thus demonstrating that DDG is a good energy source for dairy cows when the overall diet contained approximately 28% NDF and 5% fatty acids.

Our growing understanding of protein nutrition and utilization has lead us to consider the use and supply of individual amino acids (**AA**) during ration balancing procedures. Limiting AA are defined as those amino acids that are in shortest supply (Socha et al., 2005). The NRC (2001) suggests methionine (**MET**) is most limiting in rations that depend upon soy or animal protein for major RUP supply. In rations that are formulated to contain high of corn products, the supply of lysine (**LYS**) is believed to be more limiting (Liu, et al., 2000). In diets containing 20 % DDG, the supplementation of ruminally protected lysine and methioine may result in an increase in milk protein percent and yield (Nickols et al., 1998), but this has not been observed in all studies (Liu et al., 2000). When balancing diets containing high levels of DDG, nutritionists should evaluate the proportion of predicted lysine and methinone in the metabolizable protein (**MP**) fraction. More specifically, nutritionists should strive for a lysine to methionine ratio (**LYS:MET**) of 3.0:1.0. Although in most situations, this bench-mark may be difficult to reach, nutritionists may improve the amino acid profile of the ration by increasing the inclusion rate of high-LYS protein supplements such as fish meal or soy-products.

Feeding distillers grains in replace of corn grain is useful in providing energy in the form of fermentable fiber. Because fiber is digested at a slower rate than other forms of energy such as starch, feeding DDG to ruminants may be useful in reducing the incidence of rumen acidosis (Klopfenstein et al. 2001). Distiller's grains typically contain 34% neutral detergent fiber (NDF) and 13% fat on dry matter basis. Energy requirements for maintenance and milk production are expressed in net energy for lactation ($NE_L$) units. The current NRC (2001) publication outlining the nutrient requirements for dairy cattle calculates an $NE_L$ value on the total diet. Even though the energetic contribution of individual feeds is a function of other feeds included in the diet, there is interest in knowing the baseline $NE_L$ value of individual feeds because most formulation programs require $NE_L$ as a nutrient input. The energy content of DDG, when replacing corn and soy bean meal, has recently been evaluated (Birkelo et al., 2004).This research suggests that the $NE_L$ value for wet DDG is 1.03 Mcal/lb and is 10-15% higher that the current NRC listing. This and other research supports the suggestion that CDG is an excellent ruminant feed and that the digestible fiber portion of this feedstuff is a valuable source of energy. Nutritionists should be reminded that the $NE_L$ value of DDG may be variable and depend on several factors including the chemical composition and the digestibility of the feed itself (most notably NDF and fat), the level of intake and the nature of other ingredients fed to the animal.

It is impossible to recommend an optimal inclusion level of distillers grains, as it depends upon many factors including price and the nutrient content of all available feedstuffs. A number of investigators have evaluated the effects of increasing levels of distillers grains in replacing both forages and concentrates (Powers et al., 1995; Owen and Larson, 1991; Garcia et al., 2004; Kalscheur et al., 2004; Leonardi et al., 2005). Conservative estimates from these studies suggest that 15-20% of the ration DM may be included in a properly formulated ration for a lactating cow. Research also suggests that the addition of CDG to dairy diets usually results in an increase in DMI (Nichols et al., 1998; Powers et al., 1995; Owens and Larson, 1991); however this is not observed in all cases (Leonardi et al., 2005 and Schingoethe et al., 1999). Nevertheless, the increase in DMI is not surprising given that intake is influenced by feed particle size and digesta passage rate (Beauchemin et al., 2005) both of which have been demonstrated to increase in diets containing milling co products (Boddugari et al. 2001).

*Corn Gluten Feed and Lactational Performance*

A number of investigators have evaluated the effects of replacing forages and concentrates with wet CGF on dairy cattle performance. Armentano and Dentine (1988) substituted corn and soybean meal with wet CGF in rations containing a high proportion of alfalfa silage. Results suggested that wet CGF could be included at 36% of the ration DM without affecting intake, milk production or composition. More recently, VanBaale et al. (2001) observed that when fed diets containing 20% wet CGF, cows consumed more dry matter and produced more milk than those consuming diets higher in alfalfa hay, corn silage, and corn grain. In contrast to these studies, Schroeder (2003) observed that inclusion of wet CGF over 15% of the ration dry matter was associated with a decrease in milk yield. Boddugari et al. (2001) demonstrated that a wet corn milling product, similar to wet CGF, may be effective in diets for lactating dairy cows. When used to replace concentrate, the product could be included at 45% of the ration DM and at over 60% when used to replace corn and forage. In a feeding trial involving 30 cows, these investigators also observed that, on average, cows consumed less feed but produced over 5 kg more milk when the wet CGF replaced 50% of the concentrate and 30% of the forage of the control diet. These results suggest that the optimal inclusion level depends upon the feedstuffs being substituted for, as well as other ingredients contained in the ration.

*Effective Fiber Corn Milling Co-Products*

Effective fiber is the portion of the diet that is believed to stimulate rumination, chewing activity and saliva secretion, all which is designed to help to maintain healthy rumen function and normal pH levels. Nutritionists are often concerned about rumen pH because when pH levels fall below 6.0, fiber digestion may be impeded and milk fat levels may become depressed (Russell and Wilson, 1996). It is believed that rumen pH is a function of lactic acid and VFA production and is buffered by saliva (Maekawa et al., 2002). Because of this finding, it is a common practice to feed diets of longer particle size, therefore a greater amount of effective fiber, so that salvia production is stimulated. In support of this hypothesis, Krause et al. (2002) noted that the intake of particles > 19.0-mm was negatively correlated with the amount of time rumen pH was below 5.8. However, it is also known that diets should not be excessively long or coarse as they are more difficult to mix and may induce cattle to sort out ration ingredients (Kononoff et al., 2003). When co-products are used to substitute forage in the TMR, chewing activity is believed to be reduced due to the finer particle size. Nutritionists should not necessarly use this logic in infer that feeding co-products will result in lower rumen pH. In fact it is likely that diets may be balanced diets so that the inclusion of co-products will not influence rumen pH. When evaluating a dairy diet to determine a possible risk of subclinical acidosis, it is important to also consider levels of fiber and non-structural carbohydrates, along with their associated fermentability (Yang et al., 2001). Using the Penn State Particle Separator, at least 5-10% of the particles should be at least three quarters of an inch long and the diet should contain 26-30% NDF.

## Summary and Conclusions

Feed co-products from the dry-milling industry are quickly becoming common and cost effective ingredients in ruminant diets. Current research suggests that it is possible to include DDG at 20% and CGF at over 35% of the diet dry matter of lactating dairy cows. When including these feeds into dairy diets, nutritionists should ensure that the diet contains adequate levels of lysine, NDF, and effective fiber and should be mindful of the high concentration of fat in some co-products. Distillers grains have 120 - 150% the energy value of dry rolled corn in beef finishing diets. Acidosis control is likely responsible for the higher apparent values and may be the primary advantage of using distillers grains. Drying appears to reduce the energy value. Dry grains have 120 - 127% the energy value of dry rolled corn in high-forage diets. Because of differences in the amount of steep added, wet CGF has approximately 100 - 108% the energy value of dry-rolled corn when fed at levels of 20 to 60% of diet DM

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**Figure 1.** Schematic of the wet milling industry resulting in wet or dry corn gluten feed.

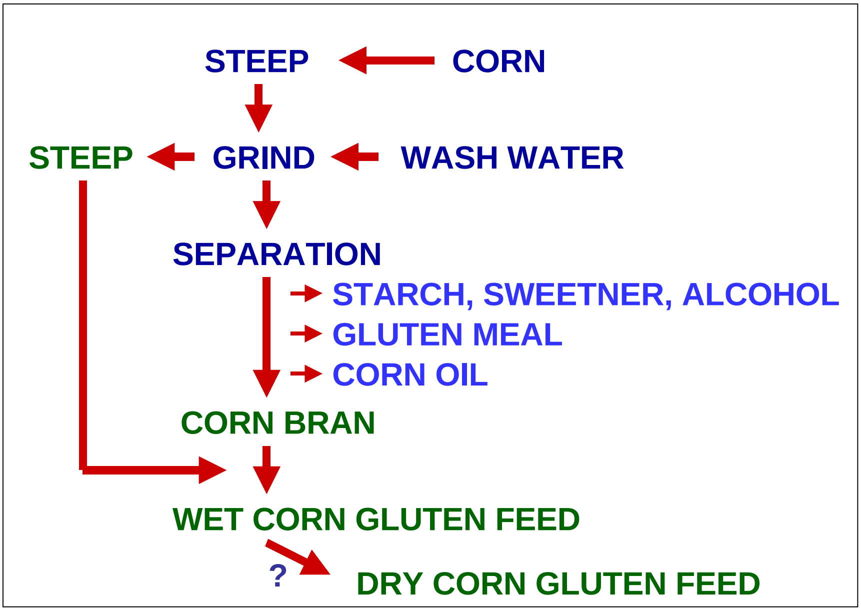

**Figure 2.** Schematic of the dry milling industry with the feed products produced.

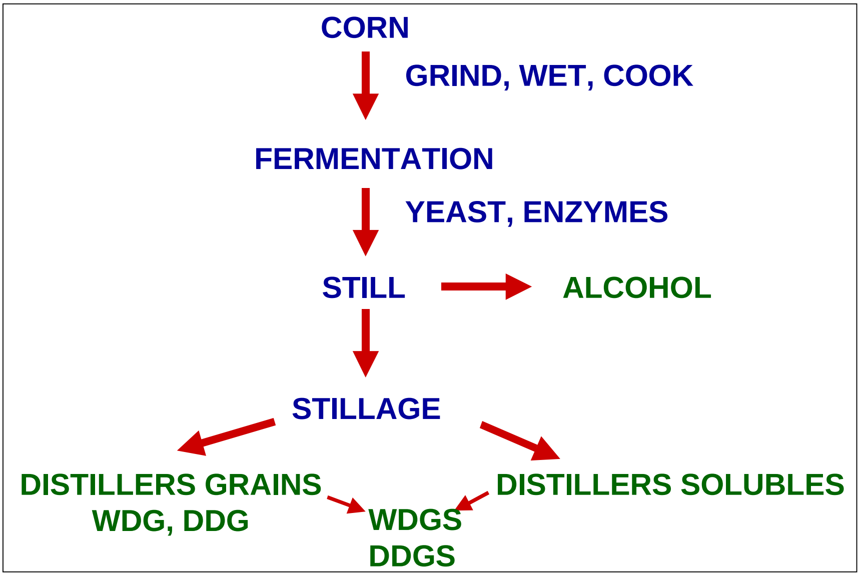


**Figure 3.** Energy content of wet distillers grains plus solubles when replacing corn at different inclusions