Feeding Dried Distillers Grains to Dairy Cattle

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Introduction

Inclusion of distillers grains in dairy diets has been intensely studied for many years. For example, in the classic text entitled *Feeds and Feeding* (1898), W.A. Henry describes a Finish study published in 1893 which reported that compared to cows consuming oats, those consuming corn-whiskey distillers grains produced 12% more milk and 9% more milk fat. A later version of this text (1911) estimated an annual production of merely 60,000 metric tons. This is in stark contrast to today where it is estimated that the U.S alone produces 13 million metric tons of distillers grains from corn-ethanol production. This also illustrates that dairy cattle can effectively utilize feed byproducts and that this fact is not new. However, it is type and chemical composition of products available that continue to change, and the supply continues to grow whereby presenting new challenges to the dairy producer and feed industry. The feed industry plays an integral role in the ethanol production industry. Specifically, the primary product of the dry milling production process is ethanol; however, 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, and thus, co-products will be an increasingly cost effective and available feedstuff.

Corn Milling Process and Associated Co-Products

Dry Milling

The dry milling industry produces the following feed products: distillers grains, dry distillers grains + solubles (DDGS), and distillers solubles. Depending on the plant, and whether it is producing a wet or dry feed, the proportion of distillers grains and distillers solubles that are mixed together may vary. However, wet distillers grains plus solubles are approximately 65% distillers grains and 35% distillers solubles (DM basis). The dry milling process (Figure 1) is relatively simple. Specifically, corn (or other starch sources) is ground and fermented, and the starch is 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 DDGS will contain approximately 12% oil.

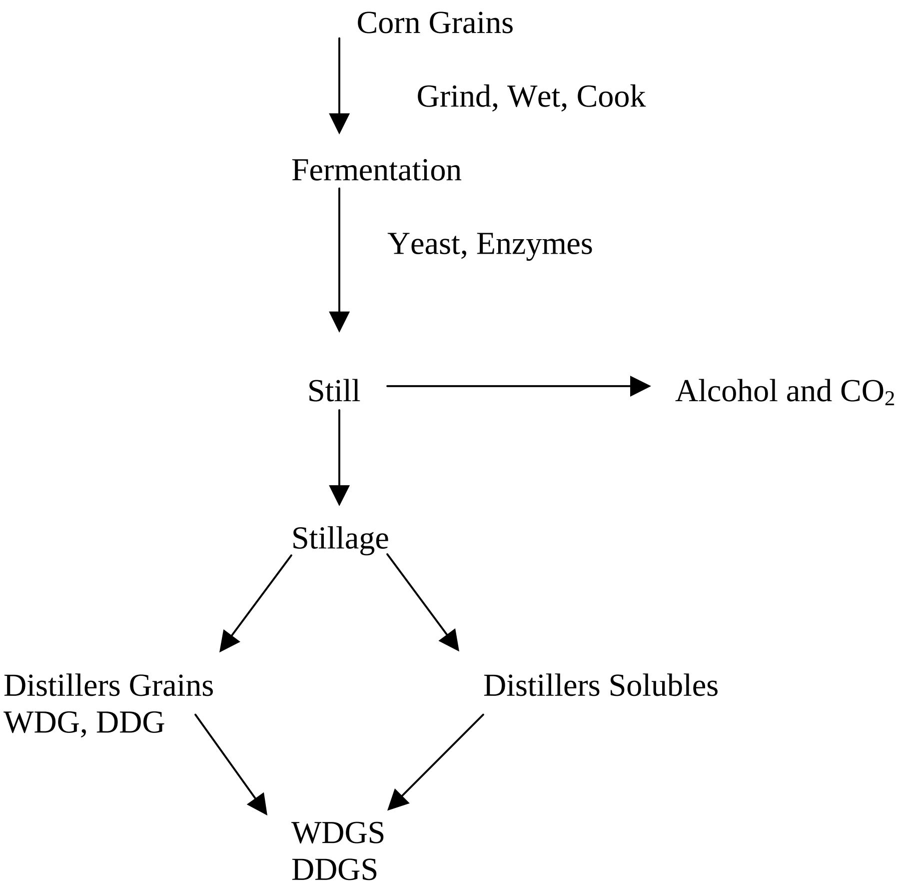

Figure 1. The dry milling process

Chemical Composition and Nutrient Availability of Distillers Grains

The chemical composition of distillers grains is different from that of the original feedstock used going into the ethanol production process. For example, Table 1 lists the chemical composition of corn and corn dried distillers grains plus solubles. Table 2 lists the chemical composition of wheat distillers grains (no solubles). In Table 1, perhaps the most noticeable difference between corn and DDGS is the increased proportion of CP in DDGS (30.5 versus 9.5% CP for DDGS and corn respectively). Logically, the proportion of starch is also much lower in DDGS (9.9%) compared to corn (70.6%). Together, these simple observations support the historical use of DDGS as replacements for high protein containing feedstuffs such as canola or soybean meal.

Table 1. Chemical composition of dry ground corn compared to DDGS using Dairy One Forage Analysis Lab results, April 25, 2007

	n[1]	Shelled Corn	Normal Range	n	DDGS[2]	Normal Range
DM, %	4,135	90.3	86.7 – 94.0	2,310	87.3	77.4 – 97.2
CP, %	3,578	9.51	7.86 – 11.2	2,234	30.3	26.6 – 33.9
ADICP, % DM	1,090	0.56	0.00 – 1.69	1,882	4.92	2.85 – 6.99
NDICP, % DM	1,092	0.92	0.57 – 1.27	535	9.70	6.22 – 13.19
Lignin, %	1,288	1.16	0.79 – 1.53	535	5.52	3.50 – 7.55
ADF, %	2,225	3.45	1.86 – 5.05	1,870	16.8	12.9 – 20.7
NDF, %	2,250	9.79	6.56 – 13.0	1,845	33.5	28.6 – 38.4
Starch, %	1,495	70.6	65.5 – 75.7	1,053	5.85	2.45 – 9.25
NFC[3], %	1,593	76.6	71.9 – 81.3	1,551	25.9	19.0 – 32.8
Ether Extract, %	1,829	4.35	3.00 – 5.70	1,601	13.0	10.0 – 15.9
Ash, %	1,482	1.54	1.02 – 2.06	601	5.92	4.74 – 7.10
NDFD[4], 24hr (%NDF)	13	30.1	0.00 – 83.4	16	51.1	42.2 – 60.0
NDFD[4], 30hr (%NDF)	27	47.4	10.6 – 84.2	18	59.2	46.9 – 71.5
NDFD[4], 48hr (%NDF)	10	68.2	50.3 – 86.0	16	70.0	57.3 – 82.6
Ca, %	1,923	0.05	0.00 – 0.18	1,501	0.09	0.00 – 0.23
P, %	1,916	0.32	0.22 – 0.43	1,518	0.92	0.77 – 1.06
Mg, %	1,902	0.12	0.02 – 0.23	1,495	0.32	0.27 – 0.37
K, %	1,906	0.41	0.30 – 0.52	1,495	1.07	0.87 – 1.27
Na, %	962	0.03	0.00 – 0.21	1,248	0.20	0.00 – 0.40
S, %	1,451	0.10	0.00 – 0.20	1,047	0.65	0.46 – 0.83

[1] Number of samples

[2] DDGS = Distillers grains plus solubles

[3] NFC = Nonfiber carbohydrates calculated by difference 100 – (%NDF + %CP + %Fat + %Ash)

[4] Invitro NDF digestibility

Table 2. Chemical composition of wheat distillers grains (Penner and Christensen. 2004).

	WDDGS
DM, %	25.8
CP, %	28.8
ADICP, % DM	18.9
NDICP, % DM	8.43
Lignin, %	6.2
ADF, %	21.8
NDF, %	54.6
Starch, %	0.86
NFC[1], %	13.8
Ether Extract, %	10.7
Ash, %	2.64
NDFD[2], 24hr (%NDF)	41
NDFD[2], 48hr (%NDF)	59
Ca, %	0.12
P, %	0.48
Mg, %	0.16
K, %	0.38
Na, %	0.14
S, %	0.40

[1] NFC = Nonfiber carbohydrates calculated by difference 100 – (%NDF + %CP + %Fat + %Ash)

[2] In vitro NDF digestibility

Recent research at the University of Nebraska-Lincoln has evaluated both the rumen undegradable protein (RUP) values and the intestinal digestibility of this protein (dRUP) (Kononff et al. 2007). Using 16 h in situ incubations, we observed the RUP of DDGS averaged 43.0 % CP, which was higher than soybean meal (28.4 %CP) but not as high as non-enzymatically browned SBM (75.7% CP). A large proportion of this protein was also digested in the small intestine (86.2 % CP), although it was slightly lower than soybean meal and non-enzymatically browned SBM (98 and 96% respectively). Although studied to a lesser extent, protein in wheat distillers grains has also been demonstrated to have a bypass potential (RUP = 62.9 % CP**)** with a large proportion being digested in the small intestine (91.1% total tract N disappearance) (Boila et al., 1994).

The CPM-Dairy model fractions feed N into 5 fractions (Table 3). These fractions are as follows A (NPN; soluble in borate-phosphate buffer but not precipitated with tungstic acid), B1 (rapidly degraded true protein; soluble in borate-phosphate buffer and precipitated with tungstic acid), B2 (moderately degraded true protein and large peptides; calculated as the difference between total CP and the sum of the other 4 CP fractions), B3 (slowly degraded true protein; calculated as the difference between neutral detergent insoluble CP [NDICP] and acid detergent insoluble CP [ADICP]), and C (undegraded true protein; measured as ADICP) (Schwab et al., 2003). For corn and wheat distillers grains, estimations of these protein fractions are listed in Table 3. For corn distillers grains default values are as follows (expressed as %CP): A, 12%; B1, 2%; B2, 58%; B3, 12% and C, 17%. For wheat distillers grains (Penner and Christensen, 2004), protein fractions are estimated to be: A, 5.4%; B1, 10.6%; B2, 50.0%; B3, 18.0% and C, 16.0%. These differences indicate that rumen availability of protein between the two feeds may be different, specifically in fractions A and B1, but given that both are highly available, it is unlikely that this may affect milk production to any great extent. The availability of this protein is in part influenced by the estimation of ADICP. It should be noted that although using ADICP may be useful in understanding the availability of ruminal N, it has been demonstrated to be a poor predictor of total protein utilization and that large differences in ADICP do not affect animal performance (Klopfenstein, 1996).

Table 3. Protein Fractions and degradation rates of corn, wheat distillers grains, canola and SBM.

			Composition (% of CP)			
CPM Fractions	**Description**	**Rumen Degradation Rate (%/h)**	**Type of Feed**			
			Corn DDGS	**Wheat DG**	**Canola**	**SBM**
A	Soluble NPN and Peptides	Instantaneous	12	5	11	11
B1	Soluble proteins and cell contents	**200 - 300**	2	11	21	9
B2	Insoluble Cell contents	5 - 15	58	50	57	77
B3	Insoluble cell wall	0.1 - 1.5	12	18	4	1
C	Cell wall, unavailable N bound to lignin	0	17	16	6	2

It has only been recently that DDGS have been extensively thought of as source of energy to replace forage fiber and non-fiber carbohydrate in dairy diets. Feeding distillers grains to replace corn grain is useful in providing energy in the form of fermentable fiber. Because fiber is digested at a slower rate and less lactic acid may be produced compared to other energy sources such as starch, feeding DDGS to ruminants may be useful in reducing the incidence of rumen acidosis (Klopfenstein et al. 2001). Compared to corn, DDGS contains a higher proportion of NDF (33.5 versus 9.75%), and this NDF is not highly lignified thus it is also highly digestible. Again, commercial and publicly available data sets have reported 24 and 48 h hour *in vitro* rumen NDF digestibilities to be 50 and 58%. Research on wheat distillers grains also demonstrated that the NDF is also highly available in the rumen. In a study evaluating wet wheat distillers grains (CP=27.9%, EE=9.7 %, NDF=63.4%), Penner and Christensen (2004) observed the 24 and 48 h *in vitro* digestibility to be 41 and 66%, respectively.

A common field concern surrounding the inclusion of distillers grains into dairy diets is the potential negative effect on milk fat synthesis. This is because they contain a high concentration of unsaturated fatty acids such as C18:1 *trans* 10 or C18:2 *trans 10, cis 12* which have been to shown to directly affect the mammary glands ability to synthesize milk fat (Bauman and Griinari, 2003). Some other common feeds containing high concentrations of unsaturated fat include roasted soybean, whole cottonseed, and sunflower seed.. Clearly distillers grains are a rich source of unsaturated fatty acids, but when fed at modest levels, distillers grains should not directly affect milk fat production. However, inclusion of this feedstuff into a poorly balanced ration may have troubling consequences. In addition, when considering the inclusion of distillers grains into dairy diets, one should be aware of major factors known to affect milk fat production and be sure to balance a ration that avoids these negative consequences. This may mean that the inclusion of feeds such as whole cottonseed or roasted soybeans is not included or fed in low amounts. If these ingredients are expected to supply protein, alternative sources that are lower in fat should be considered.

Nutrient Composition of Milling Co-Products

Nutrient Variation

Investigations conducted at the University of Minnesota (Knott et al., 2004) have demonstrated there may be a high degree of variation in the nutrient content of co-products, such as distillers 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 DDGS depends on the amount of solubles that were added to the grains. Because solubles are high in fat and sulfur, both of these nutrients tend to vary in DDGS. The availability of these nutrients may also vary. Hence, researchers 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.

Distillers Grains and Lactational Performance

More recently, a number of investigators have evaluated the effects of increasing levels of corn-ethanol distillers grains in replacing both forages and concentrates (Powers et al., 1995; Owen and Larson, 1991; Leonardi et al., 2005). Conservative estimates from these studies suggest that 15-20% of the ration DM may be safely included in a properly formulated ration for a lactating cow. Research also suggests that the addition of distillers grains to dairy diets usually results in a modest increase in DMI (Nichols et al., 1998; Powers et al., 1995; Owens and Larson, 1991; Janicek et al., 2006); however, this is not observed in all cases (Leonardi et al., 2005 and Schingoethe et al., 1999). Nevertheless, the increase in DMI is somewhat predictable, 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).

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

Penner and Christensen (2004) formulated diets to test differences in milk production if cows were fed wheat or corn distillers grains. In this study, diets containing 10% dry or wet wheat distillers, as well as corn DDGS were compared to a control diet. In this study, distillers grains replaced barely grain, soy and canola meal. Although no differences in intake were observed, cows consuming wet wheat distillers grains produced slightly more milk than the control diet. Because the yield of milk fat did not increase, 3.5% FCM was not different. In this study, the yield of milk protein was increased when feeding corn DDGS and wet wheat DDGS. Similar results have been observed by others (Janicek et al., 2006) and may indicate that when cows consume these feeds, the supply of energy to the animal may be improved, and thus supporting the needs of the mammary gland to synthesize protein.

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 levels of corn products, the supply of lysine (**LYS**) is believed to be more limiting (Liu, et al., 2000). Using 16 h rumen incubation, research at the University of Nebraska-Lincoln has demonstrated that the concentration of lysine in the RUP fraction of corn DDGS (1.86% CP) is low. A similar level has been observed in wheat distillers grains (1.16%) (Boila et al., 1994).

As a consequence, it is occasionally suggested that diets containing corn distillers grains may be deficient in LYS. Interestingly enough, a reduction in milk protein yield has rarely been observed. However, it should also be noted that in most published studies, the CP content of the diet was high (i.e. > 17%) and as a consequence, the supply of lysine to the small intestine may have been adequate even if in relation to MET, the concentration was low.

It is impossible to recommend an optimal inclusion level for distillers grains, as it depends upon many factors including price and 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 easily be included in a properly formulated ration for a lactating cow. Further evidence also suggests that even greater amounts of DDGS may be fed (Janicek et al., 2006) without sacrificing production. However, at these levels, the diet may contain excessive levels of N that is poorly utilized, resulting in increased N excretion.

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 of which are designed to help 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 with a longer particle size to supply greater amounts of effective fiber which stimulate saliva production. Inaddition, the intake of particles greater than 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 finer particle size. Nutritionists should not necessarily use this logic to infer that feeding co-products will result in lower rumen pH. In fact, it is likely that diets may be balanced so 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 consider not only the levels of fiber and non-structural carbohydrates, but also 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

Over the last year, feed markets have proved volatile. However, the use of co-products represents a tremendous opportunity to reduce dairy ration costs. Assuming the price of co-products will continue to remain lower than corn grain and soybean meal, it is easy to predict that rations including co-products will be cheaper. This economic benefit underscores the growing importance of understanding how co-products may be included into dairy diets. 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 DDGS at greater that 20% 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.

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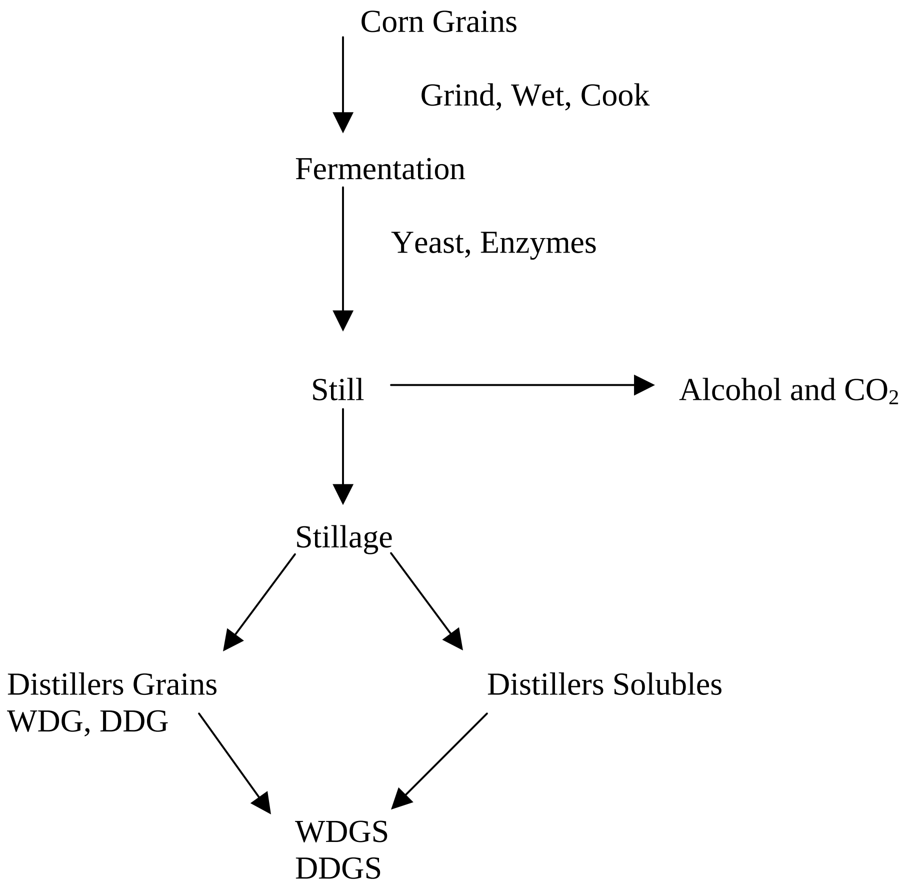

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ADF, %	2,225	3.45	1.86 – 5.05	1,870	16.8	12.9 – 20.7
NDF, %	2,250	9.79	6.56 – 13.0	1,845	33.5	28.6 – 38.4
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P, %	0.48
Mg, %	0.16
K, %	0.38
Na, %	0.14
S, %	0.40

[1] NFC = Nonfiber carbohydrates calculated by difference 100 – (%NDF + %CP + %Fat + %Ash)
[2] In vitro NDF digestibility

Table 3. Protein Fractions and degradation rates of corn, wheat distillers grains, canola and SBM.

			Composition (% of CP)			
			Type of Feed			
CPM Fractions	**Description**	**Rumen Degradation Rate (%/h)**	**Corn DDGS**	**Wheat DG**	**Canola**	**SBM**
A	Soluble NPN and Peptides	Instantaneous	12	5	11	11
B1	Soluble proteins and cell contents	**200 - 300**	2	11	21	9
B2	Insoluble Cell contents	5 - 15	58	50	57	77
B3	Insoluble cell wall	0.1 - 1.5	12	18	4	1
C	Cell wall, unavailable N bound to lignin	0	17	16	6	2