Utilization of Corn Co-Products in the Dairy Industry

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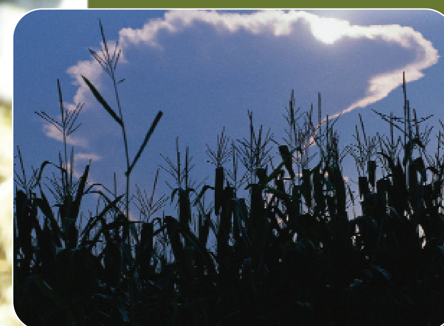

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FEEDING DISTILLERS GRAINS PLUS SOLUBLES TO LACTATING DAIRY CATTLE

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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 Finnish 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 the U.S. alone produces 13 million metric tons of distillers grains from corn-ethanol production.

Dairy cattle can effectively utilize feed co-products. However, the type and chemical composition of products available continue to change and the supply continues to grow, 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, thus becoming an increasingly cost effective and available feedstuff. 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 DRY MILLING PROCESS

In the dry milling process, a starch source such as corn, wheat or sorghum is cleaned and ground dry, and the whole kernel is used in the fermentation process to produce ethanol and carbon dioxide (Figure 1). In this case there are basically two products of interest. The first product is the solid, unfermented grain portion called wet distillers grains (WDGS) and second is the thin stillage fraction that contains water, small particles, yeast and all other soluble nutrients. If not sold as WDGS, material may be further dried yielding dried distillers grains (DDG); and in some cases the thin stillage is added back to yield dried distillers grains plus solubles (DDGS). Table 1 lists the estimated nutrient content of wet and dry corn distillers grains and the original feedstock, shelled corn.

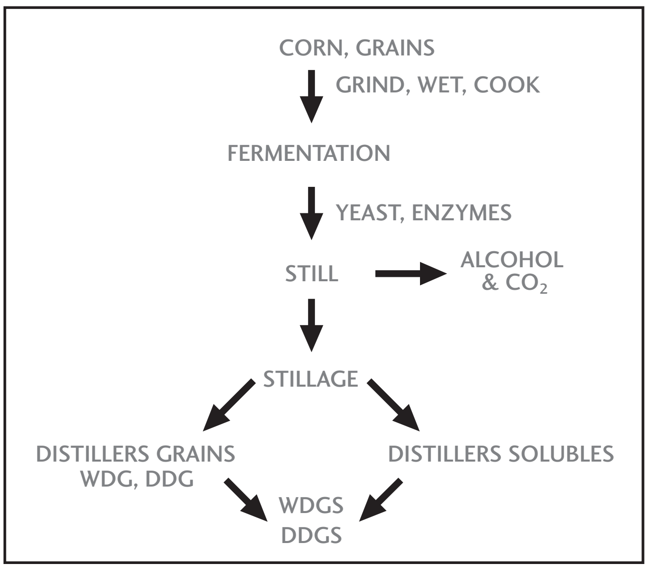

Figure 1 – Schematic of the dry milling industry with the feed products produced.

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). Approximately 1/3 of the DM remains as the feed product following starch fermentation. As a result, all the nutrients are concentrated three-fold because most grains contain approximately 2/3 starch. For example, if corn is 4% oil, the co-product will contain approximately 12% oil.

CHEMICAL COMPOSITION AND NUTRIENT AVAILABILITY OF DISTILLERS GRAINS

The chemical composition of distillers grains is different from that of the original feedstock used in the ethanol production process. For example, Table 1 lists the chemical composition of corn, and corn wet and dried distillers grains plus solubles, (WDGS/DDGS). (Note values between feeds are from different sources, thus cannot be compared statistically.) In Table 1, perhaps the most noticeable difference between corn and WDGS/DDGS is the increased proportion of crude protein (CP) in WDGS/DDGS (29.5/30.4 versus 9.4% CP for WDGS/DDGS and corn respectively). Logically, the proportion of starch is also much lower in WDGS/DDGS (6.68/5.97%) compared to corn (70.5%). Together, these simple observations support the historical use of WDGS/DDGS as replacements for high protein containing feedstuffs such as canola or soybean meal (SBM).

Protein contained in the feed can be utilized by rumen microbes. However, the rumen undegradable protein (RUP) portion may bypass the rumen and supply the small intestine with protein where it is digested and absorbed. Recent research at the University of Nebraska–Lincoln has evaluated both the RUP values and the intestinal digestibility of this protein (dRUP) (Kononff et al., 2007). Using 16 hour in situ incubations, we observed the RUP of DDGS averaged 43.0% CP, which was higher than SBM (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 SBM and non-enzymatically browned SBM (98 and 96% respectively).

It has only been recently that WDGS/DDGS have been extensively thought of as a 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 WDGS/DDGS to ruminants may be useful in reducing the incidence of rumen acidosis (Klopfenstein et al., 2001). Compared

Table 1. Chemical composition of wet distillers grains (WDGS) and dry distillers grains (DDGS). (Dairy One Forage Analysis Lab results, January 21, 2008)

	Shelled Corn			WDGS			DDGS		
	n[1]	Mean	SD[2]	n[1]	Mean	SD[2]	n[1]	Mean	SD[2]
DM, %	4745	90.1	3.53	1177	28.6	13.0	2914	87.6	8.9
CP, %	4064	9.40	1.63	1171	29.5	12.3	2805	30.4	4.1
ADICP, % DM	1452	0.53	0.99	1119	3.5	2.20	2397	4.8	2.1
NDICP, % DM	1454	0.96	0.33	720	8.11	4.3	790	9.6	3.4
Lignin, %	1655	1.17	0.34	307	5.0	2.0	830	5.3	1.9
ADF, %	2680	3.49	1.5	1088	14.4	5.9	2389	16.7	3.7
NDF, %	2710	9.76	3.0	1091	28.9	10.3	2376	33.3	4.8
Starch, %	1946	70.49	5.13	552	6.68	12.5	1433	5.97	5.39
NFC[3], %	2050	76.8	4.33	1046	32.4	19.4	2079	26.0	6.98
Crude Fat, %	2238	4.30	1.26	678	12.1	4.90	2086	13.0	3.0
Ash, %	1869	1.52	0.48	267	5.33	2.37	968	5.93	1.10
NDFD[4], 24hr (%NDF)	39	41.5	34.0	-	-	-	32	53.3	7.6
NDFD[4], 30hr (%NDF)	33	47.6	34.2	-	-	-	29	58.6	11.0
NDFD[4], 48hr (%NDF)	13	64.8	16.8	-	-	-	26	67.9	10.5
Ca, %	2344	0.04	0.12	489	0.08	0.12	1928	0.09	0.13
P, %	2338	0.32	0.10	489	0.85	0.16	1945	0.91	0.14
Mg, %	2322	0.12	0.09	489	0.31	0.07	1920	0.32	0.05
K, %	2325	0.41	0.10	489	0.97	0.30	1920	1.08	0.21
Na, %	1050	0.03	0.17	434	0.14	0.13	1554	0.19	0.19
S, %	1830	0.10	0.09	378	0.54	0.16	1421	0.64	0.18

[1]Number of samples
[2]Standard deviation
[3]NFC = Nonfiber carbohydrates calculated by difference 100 – (%NDF + %CP + %Fat + %Ash)
[4]In vitro NDF digestibility (data were not available for WDGS)

to corn, WDGS/DDGS contains a higher proportion of neutral detergent fiber (NDF) (28.9/33.3 versus 9.76%), and this NDF is not highly lignified thus it is also highly digestible. Commercial and publicly available data sets have reported 24 and 48 hour in vitro rumen NDF digestibilities of DDGS to be high (50 and 58%). Energy requirements for maintenance and milk production are expressed in net energy for lactation (NEL) units. The current NRC (2001) publication outlining the nutrient requirements for dairy cattle calculates an NEL 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 NEL value of individual feeds because most formulation programs require NEL as a nutrient input. The energy content of distillers grains, when replacing corn and SBM, has recently been evaluated (Birkelo et al., 2004). This research suggests that the NEL value for WDGS is 1.03 Mcal/lb and is 10-15% higher that the current NRC listing. This and other research supports the suggestion that WDGS/DDGS are excellent ruminant feeds and that the digestible fiber portion of these feedstuffs are valuable sources of energy. Nutritionists should be reminded that the NEL value of distillers grains 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.

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 shown to directly affect the mammary gland's ability to synthesize milk fat. Some other common feeds containing high concentrations of unsaturated fat include roasted soybeans, 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 feed such as whole cottonseed or roasted soybeans is not included or fed in low amounts. Since these ingredients are expected to supply protein, alternative feedstuffs that are lower in fat should be considered.

EFFECTIVE FIBER

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 maintain healthy rumen function and normal pH levels. When rumen pH levels fall below 6.0, fiber digestion may be impeded and milk fat levels may become depressed. It is believed that rumen pH is a function of lactic acid and other acid 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 saliva 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 WDGS or DDGS are used to substitute forage in the total mixed ration (TMR), chewing activity is believed to be reduced due to the 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 that the inclusion of co-products will not influence rumen pH. When evaluating a 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.

PHOSPHORUS AND SULFUR

The mineral content of feeds and the associated levels in livestock manure has received considerable attention. When including WDGS or DDGS into dairy diets producers should understand that although they contain many valuable nutrients, these feeds may also contain higher levels of both phosphorus (approximately 0.9%) and sulfur (approximately 0.55%). Although its is unlikely that these levels would contribute to the loss of any milk production or health problems, producers should be mindful of the importance of dealing with these minerals. Recently, the land application of dairy manure has risen to national attention and continues to face growing scrutiny because manure may accumulate minerals and has the potential to contaminate surface and groundwater. To avoid these problems, producers should ensure that their waste management plan attempts to avoid excessive accumulation of minerals and allows for maximum crop use of the nutrients contained in the manure.

WET VERSUS DRY…PRACTICAL CONSIDERATIONS

As mentioned earlier, distillers grains may be available in either a wet or dry form and the nutrient content, when expressed on a dry matter basis, is similar for both (Table 1). One possible major difference between these forms may be the fact that the RUP portion may be higher in the dry form (Firkins et al., 1984). Although it is generally believed that there is little difference in milk production when animals are fed either form, beef feedlot studies have demonstrated that rations containing WDGS are consumed in lower amounts and result in greater feed efficiencies than those containing DDGS (Ham et al., 1994). Unfortunately there has been less research investigating possible differences in milk performance. In one study in which lactating dairy cattle were fed diets containing 15% (DM basis) of either wet or dry forms, no differences were observed in milk production, composition, fiber digestibility and efficiency of milk production (Al-Suwaiegh et al., 2002).

When deciding which form may fit best, producers should evaluate several factors, including distance from plant of origin, the anticipated feeding rate, the on-farm storage facilities and handling equipment. Because a wet product may not be stored as long and is usually associated with high shipping charges, dried forms may be most feasible if a plant is not located near the farm. However, this also increases the price of the feedstuff. If the farm is located near a plant, wet forms may be cost effective, but producers should be mindful of the fact that the rate of spoiling is also dependent upon the feeding rate and environmental temperature. Generally speaking, wet loads should arrive at least weekly to ensure the pile is "fresh." There continues to be interest in ensiling feeds such as WDGS as a method to eliminate oxygen exposure and ultimately reduce feed spoiling and loss. Additionally, a number of commercial direct application preservative products may be useful in extending shelf life of these feeds, but producers should be mindful of these added costs.

CONSIDERATIONS FOR FEEDING NUTRIENT VARIATION

Recent investigations conducted at the University of Minnesota (Knott et al., 2004) have demonstrated that 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 CP 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. Along with the concentration of CP, 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. In turn, it becomes possible to protect against underfeeding a nutrient such as protein by feeding an anticipated mean value of the feed.

FEEDING LEVELS AND PRODUCTION RESPONSES

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 dry matter intake (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 barley 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, 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 hour rumen incubation, research at the University of Nebraska–Lincoln has demonstrated that the concentration of LYS 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 LYS 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 nitrogen that is poorly utilized, resulting in increased nitrogen excretion.

Table 2 lists the costs of two typical Nebraska dairy rations along with assumed ingredient costs (DM basis). These rations differ in the amount of WDGS included. In the ration to the right WDGS is included at a conservative level (15% of the ration DM) and replaces a portion of the forage, ground corn, and protein ingredients. These substitutions resulted in reduced ration costs (WDGS = $144.17 versus CONTROL, no WDGS = $158.30/T DM).

Table 2. Ration cost of typical Nebraska dairy ration with and without wet distillers grains (DM Basis).

			% Ration Inclusion[1]	
			Control	WDGS
Ingredient, %DM	% DM	$/T DM		
Wet distillers grains + solubles[2]	49.4	122.02	–	15.0
Corn silage	36.7	70.84	28.0	25.5
Alfalfa haylage	34.4	136.63	9.8	9.0
Alfalfa hay	91.5	136.61	9.8	9.0
Brome hay	84.0	113.10	3.5	3.0
Ground corn	88.0	128.44	17.5	13.5
Soybean meal	91.0	286.81	6.0	3.5
By-Pass Soy	90.0	323.33	6.0	4.0
Cottonseed	90.0	241.11	6.0	5.5
Soybean hulls	91.0	175.82	10.0	10.2
Urea	100.0	493.00	0.24	–
Tallow	100.0	700.00	1.0	–
Vitamin ADE	100.0	2330.00	0.12	0.12
Magnesium oxide	100.0	306.00	0.24	0.24
Trace mineral	100.0	684.60	0.04	0.04
Vitamin E	100.0	4600.00	0.016	0.016
Limestone	100.0	100.00	1.0	0.9
Salt	100.0	160.00	0.12	0.12
Sodium bicarbonate	100.0	352.00	0.5	0.5
Ration cost, $/T DM			158.30	144.17

[1]Control = 0% DM co-products; WDGS = 15% DM wet distillers grains + solubles

[2]Calculated as 95% cost of corn

SUMMARY AND CONCLUSIONS

Feed co-products from the dry milling industry are quickly becoming common and cost effective ingredients in dairy diets. Assuming the price of distillers grains will continue to remain lower than corn grain and soybean meal, it is easy to predict that rations including these feeds will be cheaper. This economic benefit underscores the growing importance of understanding how co-products may be included in dairy diets. Current research suggests that it is possible to include distillers grains at levels as high as 30% of the diet DM. When including distillers grains into dairy diets, nutritionists should ensure that the diet contains adequate levels of LYS, NDF and effective fiber and should be mindful of the high concentration of fat in this feedstuff.

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