USING DISTILLERS GRAINS IN DAIRY CATTLE RATIONS

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Distillers grains are co-products produced from the fermentation of grains for alcohol. Traditionally, alcohol was produced mainly for the beverage liquor industry, but in the last 20 years its use as an alternative fuel has increased significantly. This increased demand has led to the development of several ethanol production plants in Minnesota and the surrounding area. In 1996, it is estimated 135,000 tons of distillers grains will be produced from current plants with production doubling or tripling over the next five years as more ethanol plants begin operation. Thus, the opportunity exists for using a substantial quantity of distillers grains in dairy rations.

When grains are fermented to alcohol, approximately one-third of the dry matter (DM) is recovered in co-products. The two basic products at the end of the fermentation process are coarse, unfermented grains and a liquid fraction known as thin stillage containing small particles of grain, yeast and soluble nutrients. These two products are further processed into the following four co-products: 1) distillers dried grains (**DDG**), 2) distillers dried solubles (**DDS**), 3) distillers dried grains with solubles (**DDGS**), and 4) condensed distillers solubles, 30 to 40% DM (**CDS**). Both the CDS and DDS are made from thin stillage through partial (CDS) or complete (DDS) drying. Dried distillers grain with solubles is produced by adding a portion of the thin stillage back to the unfermented grain fraction at the time of drying. The two primary co-products used in the feed industry are DDG and DDGS.

Alcohol can be produced from one or any combination of cereal grains. The most commonly used grains are corn, milo, wheat, barley and rye. The grain used in the largest quantity is used to name the resulting product. For example, corn distillers grains would be produced from a fermentation batch where corn was the primary grain used.

As the names imply, most distillers grains are produced in a dry form. This results in ease of handling, storage and shipping to local or foreign markets. The effects of drying on nutrient availability have been of some concern and debated in various research studies. Wet distillers grains are available in some areas. This reduces the energy costs of drying but increases their perishability and handling problems for the feeder.

Nutrient Composition

The typical nutrient content of corn-based distillers grains is shown in Table 1. In general, distillers grains are devoid of starch but a good source of energy, protein, fiber and phosphorus. The nutrient content of distillers grains is about three times more concentrated than the nutrients in the original grain before fermenting. Yeast cells also are quite high in distillers grains (10).

The yeast species *Sacchsromyces cerevisiae* is commonly used for fermentation, as it is an efficient producer of alcohol. Yeast concentrations often reach 150 million cells per cubic centimeter in mashes after just 26 hours of fermentation.

Table 1. Nutrient composition of common corn distillers co-products.[1]

Nutrient[2]	Distillers grains (DDG)	Distillers grains + solubles (DDGS)	Condensed distillers solubles (CDS)
DM, %	94	92	93
CP, %	23	25	30
NE_L, Mcal/lb	.90	.93	.93
TDN, %	86	88	88
Fat, %	10	10	9
ADF, %	17	18	7
NDF, %	43	44	23

[1] NRC, 1989 (14).

[2] All nutrients except DM expressed on a DM basis.

The nutrient content of distillers grains can be influenced by a number of factors. The primary factors are the type of grain (Table 2), milling process, grain quality, fermentation process, drying temperature and amount of solubles blended back into the unfermented fraction at the time of drying. Chase (4) showed ranges in the DM content of DDGS as follows: crude protein (CP) - 22 to 33%, neutral detergent fiber (NDF) - 29 to 64%, and fat - 2 to 20%. Purchasers of distillers grains must be cognizant of variations in nutrient content. When purchasing distillers grains, it is important to know what grain or combination of grains were used in the fermentation. Distillers grains should be tested for DM, CP, acid detergent fiber (ADF), NDF, ADF insoluble nitrogen (ADIN) and fat.

Of particular interest to dairy nutritionists is the undegradable intake protein (UIP) or "bypass" protein content. Values published by the NRC (14) for UIP of corn DDG and DDGS are 54 and 47% of the CP. More recent results have shown corn-based DDGS to vary from about 45% (17) to 55% (9). Stern et al. (20) analyzed five samples of distillers grains and found a UIP of $56 \pm 8\%$ with an intestinal digestibility of the UIP at $81 \pm 5\%$. Grings et al. (9) reported the intestinal digestibility of UIP in DDGS was 93%. Soluble intake protein (SIP) of distillers grains was estimated by Chase (4) to be about 15% of the CP, but more recent research (17) has shown it to be about twice that value (28.5% of the CP).

The amino acid profile of two corn and one milo DDGS is shown in Table 3. With today's emphasis on balancing amino acids in the diets of dairy cows, knowing the amino acid content and the variation that can occur in high bypass protein sources like DDGS is important. Dong et al. (16) evaluated the amino acid profiles of several wheat DDGS and found profiles in the DDGS to be similar to the whole grain before fermentation.

Table 2. Nutrient composition of some non-corn distillers dried grains with solubles (DDGS).[1]

Nutrient	Barley DDGS[2]	Rye DDGS[3]	Wheat DDGS[4]
DM, %	88		96
CP, %	29	29	44
ADF, %	29	20	16
NDF, %	56		36
ADIN, % of CP	39		10

[1] All nutrients except DM expressed on a DM basis.

[2] Weiss et al. (22).

[3] Shelford and Tait (18).

[4] Boila and Ingalls (3).

Table 3. Amino acid profile of corn and milo distillers dried grains with solubles (DDGS).

Amino acid	Corn DDGS[1]	Corn DDGS[2]	Milo DDGS[1]
	------------------------------	% of DM	------------------------------
Lysine	.70	.47	.95
Methionine	.60	.63	.50
Histidine	.70	.76	.69
Arginine	1.05	1.05	2.40
Threonine	.93	1.01	.92
Leucine	2.23	3.42	4.98
Isoleucine	1.52	1.12	.92
Valine	1.63	1.55	1.07
Phenylalanine	1.51	1.27	1.47
Tryptophan	.20		

[1] Distillers Feed Research Council, Des Moines, IA.

[2] Powers et al. (17).

Grains are generally low in fiber and considered an insignificant fiber source in diets for dairy cattle. However, concentration of the fiber by removal of starch during fermentation results in DDG and DDGS being a very good source of nonforage fiber for dairy cattle. The NDF content of distillers grains is typically 35 to 40% of the DM (Table 1). However, the fiber is very short in particle length and, therefore, raises questions as to its effectiveness in stimulating cud chewing. The effective fiber values of nonforage fiber sources have been determined by either their physical characteristics and how they contribute to rumen mat formation and cud chewing or by their ability to support a “normal” milk fat percentage when used to replace forage fiber in a diet (1, 8). Bhatti and Firkins (2) indicated the digestion of NDF in distillers grains is rather slow initially, but once initiated the digestion rate was relatively fast (.0626/hour). The slow initiation could be a reflection of the low water holding capacity (.062g/g of insoluble DM) of NDF in distillers grains, as fiber must be hydrated before digestion by bacteria (2). The slow initial digestion rate in combination with a small particle size can result in a fast rate of passage from the rumen. Thus, the physical effectiveness of NDF in distillers grains to stimulate cud chewing appears to be quite limited.

The use of milk fat percentage as a measure for effective fiber is based on the digestion of fiber in the rumen and not the physical attributes needed for stimulation of cud chewing. Firkins (8) indicated the NDF in nonforage fiber sources like DDS or DDGS are less than half as effective as forage NDF sources in stimulating cud chewing. Thus, the effective fiber values for nonforage feeds based on milk fat percentage represents their ability to substitute for nonfiber carbohydrates (NFC) in diets rather than stimulate cud chewing. Using the milk fat percentage method, Clark and Armentano (5) determined DDG had an effective NDF value equal to that of alfalfa haylage. In comparison with corn silage NDF in maintaining milk fat percentage, Staples et al. (19) found DDGS NDF was 68% as effective. However, in diets high in corn silage and considerably above NRC minimum fiber recommendations the effectiveness of NDF in DDGS was negative. In other words, replacing corn and soybean meal with DDGS in diets high in NDF decreased milk fat percent.

Evaluating Protein Quality

Extensive heating of distillers grains during the drying process has raised questions about the nutrient availability, especially protein, in DDS and DDGS. The effects of excessive heating on reducing protein availability to animals has been well documented. Acid detergent insoluble nitrogen (ADIN) or the amount of nitrogen in the ADF fraction has been used as an indicator and measure of the protein availability reduction in a feed due to heat damage. Chase (4) extensively reviewed the use of ADIN as a method utilized to estimate heat damaged protein in distillers grains and other co-products. He concluded that ADIN, although not perfect, can be a good “index” for measuring heat damage in feeds.

Nakamura et al. (13) found a range in ADIN from 7.8 to 27.9% of the total nitrogen in distillers grains from seven different distillers. A relationship between ADIN and “bypass” protein content of the distillers grains was evident ($r^2 = .55$); however, the correlation with true digestibility of nitrogen in distillers grains was very low ($r^2 = .24$). An average of 78% of the ADIN in the seven samples of distillers grains was digested by sheep. Additional research by Klopfenstein (11) suggested some of the nitrogen associated with ADIN can be absorbed from the digestive tract but may not be efficiently utilized by the animal for growth. The biological availability of amino acids such as lysine appears to be reduced during the heating process.

Protein solubility is not a good estimator of ADIN content in distillers grains. Both Chase (4) and Powers et al. (17) demonstrated either a very poor or no correlation between ADIN and soluble protein, expressed as percent of CP, content in distillers grains.

An early biological indicator of heat damage in distillers grains may be a reduction in milk protein percentage when fed to lactating cows. Van Horn et al. (21) observed a reduction in milk protein percentage in cows fed DDGS with a high ADIN content (32.9% of the total nitrogen) compared to cows fed soybean meal. Others (15, 16) have observed similar results. However, it is unclear whether the reduction in milk protein percentage was caused solely from a high ADIN content in distillers grains or an imbalance of amino acids in these diets, namely low lysine, created by the substitution of distillers grains for soybean meal. When feeding diets containing both soybean meal and DDGS, Powers et al. (17) observed a slight decline in milk protein percentage only when the DDGS source contained more than 20% of the nitrogen in the ADIN fraction.

There appears to be conclusive evidence that animal performance is diminished in some manner when heat damaged protein feeds are fed. The exact level of ADIN in DDG or DDGS where a depression in animal performance occurs is unknown. However, color of distillers grains appears to be associated with amount of ADIN (17). Good, high quality distillers grains will have a honey golden to caramelized golden color. Color progressing towards dark coffee grounds is an indicator of excessive heating during the drying process and the potential for high levels of ADIN.

Research Studies with Distillers Grains

Early research work on feeding distillers grains to dairy cattle has been summarized in a 1991 review by Chase (4). Performance results from these studies were inconsistent. In studies where increases in milk yield or milk components were found, the forage base of the diet was alfalfa or a mixture of alfalfa and corn silage. Decreases in milk production or milk components from feeding distillers grains were associated with high levels of ADIN in DDGS and with all or very high levels of corn silage in the diet. Current knowledge would indicate that the studies reporting lowered milk production resulted from reduced microbial growth in the rumen and a low dietary lysine content as the primary source of dietary protein was from corn products.

Since 1991, five research studies evaluating the use of distillers grains in lactating dairy cow diets were found. These are summarized below and in Table 4.

Owen and Larson (15) reported the results of a study comparing DDGS and soybean meal in diets for early lactation cows. The dietary DM fed in this study consisted of 50% ammoniated corn silage and 50% concentrate. Milk production of cows fed DDGS or soybean meal was equal when DDGS was included in the diet at 19% of the DM (low CP diet - 14.5%) but decreased when DDGS was included at 36% of the DM (high CP diet - 18%). The authors concluded that the poor performance of cows fed the high DDGS diet was from poor digestibility and a shortage of available lysine. The decrease in milk protein percentage on both the high and low CP diets with feeding of DDGS compared to soybean meal also indicates available lysine was deficient in these corn based diets (Table 4).

The substitution of DDGS for ground corn in early lactation diets was evaluated by Grings et al. (9). The diets were alfalfa-based and contained 61% concentrate with DDGS at 0, 10.1, 20.8 and 31.5% of the dietary DM. Crude protein content of the diets increased with increasing DDGS amounts (13.9, 16.0, 18.1 and 20.3%). Milk yield and milk protein percentage increased linearly with increasing dietary CP (Table 4). Dry matter intakes were not different among the four treatments; however, fat and UIP intakes increased and NFC intakes decreased as DDGS in diets increased. The beneficial response to increasing CP in alfalfa-based diets up to 18.1% by the addition of DDGS was attributed to an increased intake of CP, UIP and essential amino acids. Intestinal availability of UIP in the DDGS fed in this study was determined to be 93%.

Using a Latin square design with mid-lactation cows, Clark and Armentano (5) determined the effect of replacing alfalfa NDF with NDF from DDG on milk production and composition. Although this was only a short term study with objectives to measure fiber effectiveness, substituting DDG for 12.7% of the alfalfa DM in the diets resulted in both a milk production and milk protein percentage increase (Table 4).

Powers et al. (17) compared the performance of mid- and early-lactation cows fed 14 or 18% CP diets containing DDGS from three different sources or soybean meal with and without blood meal. Amounts of DDGS in diets were 13% of the DM in the 14% CP diet and 26% of the DM in the 18% CP diet. The three sources of the DDGS are designated as 1, 2 and 3. All diets were a 50:50 forage to concentrate ratio (DM basis) with corn silage as the sole forage. The DDGS from sources 1 and 2 (DDGS-1 and DDGS-2) were lower in ADIN (13 and 17% of the CP, respectively) and lighter in color than the third source (DDGS-3) with 21% ADIN. Production results are shown in Table 4. Dry matter intakes were not affected by either source or amount of CP in the diet. Milk productions from cows fed either DDGS-1 or DDGS-2 were higher than those of cows fed soybean meal. Milk production of cows fed DDGS-3 was similar to cows fed soybean meal. Milk yields were higher with 26% DDGS than with 13% DDGS included in diets. Milk protein percentage was decreased with feeding DDGS-3. The authors indicated that quality differences in DDGS do affect animal performance and need to be considered when DDGS is fed. They concluded that color and ADIN content of DDGS along with milk protein percentage are good indicators of DDGS quality.

Staples et al. (19) evaluated the effects of DDGS on the performance of dairy cows fed corn silage-based diets varying in concentrate to forage ratio. Three concentrate to forage ratios were fed (70:30, 55:45 or 40:60) with either 0 or 20% DDGS in the dietary DM. With increasing concentrate level in the diet, a linear increase in DM intake and milk production and a linear decrease in milk fat percentage was observed (Table 4). Feeding DDGS in replacement of corn and soybean meal resulted in about 2.5 lb more milk per day. The effectiveness of NDF in DDGS in elevating milk fat percentage when fiber deficient diets are fed was determined to be about 68% as effective as corn silage NDF.

Table 4. Distillers grains production trials.

Reference	CP	Conc	DDGS	DM	Milk	Fat	Protein
				Production measures			
	---------- % of diet DM ----------			------ lb/day ------		--------- % ---------	
15	Base forage - Ammoniated corn silage						
	13.9	50	9	49.0	71.7	3.55	2.89
	14.6	50	0	52.2	74.5	3.65	2.99
	14.6	50	19	55.3	75.6	3.62	2.76
	18.7	50	0	52.9	75.2	3.68	3.03
	17.7	50	37	50.7	62.8	3.76	2.77
9	Base forage - Alfalfa						
	13.9	61	0	55.8	83.3		2.63
	16.0	61	10.1	58.0	88.6		2.66
	18.1	61	20.8	58.2	92.4		2.78
	20.3	61	31.6	58.4	92.6		2.80
5	Base forage - Alfalfa						
	19.9	56.4	0	50.3	67.5	3.30	2.98
	20.1	69.1	12.7	53.6	71.7	3.27	3.09
17	Base forage - Corn silage						
	14	50	0	53.1	58.6	3.38	3.14
	14	50	13 (1)[1]	52.9	58.9	3.53	3.13
	14	50	13 (2)	52.4	61.0	3.45	3.15
	14	50	13 (3)	52.0	58.2	3.39	2.95
	18	50	0	51.8	60.3	3.49	3.17
	18	50	26 (1)	54.2	63.0	3.52	3.26
	18	50	26 (2)	53.2	62.2	3.34	3.12
	18	50	26 (3)	53.8	60.4	3.59	3.08
19	Base forage - Corn silage						
	16.1	40	0	46.7	56.1	3.78	
	16.5	55	0	51.3	59.1	3.60	
	15.8	70	0	54.2	61.4	3.44	
	16.4	40	20	46.1	60.3	3.69	
	16.5	55	20	50.9	60.7	3.64	
	16.4	70	20	51.7	63.9	3.57	

[1] Number in ( ) indicates source of DDGS (see text for explanation).

Feeding Recommendations

Distillers grains are a palatable, high energy, fiber feed and a good source of UIP for use in feeding dairy cows. Based on the research reviewed, DDGS or DDG can comprise up to 26% of the dietary DM fed to dairy cows. The basic limit as to the quantity of distillers grains that can be fed will be determined by the CP and UIP content of the diet. Because distillers grains are relatively high in UIP (55% of the CP), feeding high amounts of distillers grains can result in low rumen ammonia levels and deficiency of DIP in the diet. Also, the profile of amino acids in the diet as well as those presented to the intestine must be considered when distillers grains are included in rations. Balancing diets for SIP, DIP and UIP along with consideration of CP, lysine and methionine can minimize many of the problems and negative effects observed with feeding distillers grains in research studies.

In addition to the above, it is advisable to limit the amount of CP coming from corn sources in a ration to less than 60% of the total CP. Corn protein sources would include corn silage, corn grain, corn DDGS, corn gluten meal and corn gluten feed.

The NDF in distillers grains is effective in maintaining milk fat percentage but is relatively ineffective at stimulating cud chewing. Therefore, distillers grains is an effective substitute for NFC in diets but has limited forage fiber replacement abilities. If the minimum amount of forage in the diet meets the physically effective fiber requirement for cud chewing, then distillers grains can be used to replace any additional forage fiber needed in the diet. The effective replacement rate of NDF in distillers grain for forage fiber is considered to be about 66%. Therefore, for every 1 lb of forage NDF needed in a diet, 1.5 lb of NDF from distillers grains must be added.

Economic Considerations

Several approaches are available to estimate the economic value of distillers grains as well as other feeds (7). In any pricing considerations, nutrient variability along with ease of handling and storage, overall feed quality and animal acceptance must be considered.

The preferred method of pricing is a least-cost ration as this evaluates the use of all feeds under consideration for the diet under a well-defined set of nutrient requirements. However, in many situations a quick comparison of one feed against one or two other feeds based on protein and energy value is all that is desired. The following methods can be used to obtain a quick comparison of economical value for DDGS:

1. Price based on cost/unit of CP or UIP.
   $/unit of CP or UIP = $/unit of feed / (unit of feed x DM x CP or UIP)

   Example:

   Cost of CP from soybean meal (49.9% CP, DM basis; 89% DM)
   $/lb of CP = $250/ton / (2000 lb x .89 x .499) = $.28/lb of CP

   Cost of CP from DDGS (28% CP, DM basis; 92% DM)
   $/lb of CP = $150/ton / (2000 lb x .92 x .28) = $.29/lb of CP

Similar calculations can be made for UIP

Example:

DDGS (where UIP is 55% of CP)
$/lb of UIP in DDGS = $150/ton / (2000 lb x .92 x .28 x .55)
= $.53/lb of UIP

2. Equation to price DDGS in relation to corn (energy source) and soybean meal (CP source).

   All feeds must be priced on a common unit basis ($/cwt or $/ton) and on an equal DM basis such as air dry (90% DM).

   Corn = $7.14/cwt   Soybean meal = $12.50/cwt

   $/cwt of DDGS = ($ of corn x .531) + ($/cwt of soybean meal x .514)
   = ($7.14 x .531) + $12.50 x 514)
   = $10.22/cwt or $204.40/ton

3. Another way of pricing DDGS based on protein and energy is against a mix of soybean meal, corn and fat which is equal in CP and energy to the DDGS. An example of a 100 lb mix equivalent to DDGS of 25% CP, 9% fat and 86 Mcal of NE_L (as fed basis) is:

	lb/100 lb of mix	x	$/lb	=	$/100 lb of mix
Soybean meal	47.5	x	.1250	=	5.94
Corn	46.0	x	.0714	=	3.28
Tallow	6.5	x	.25	=	1.62
Total					$10.84 / 100 lb of DDGS

Feeding Wet Distillers Grains

For some dairy producers, feeding wet distillers grains (WDG) directly from an alcohol plant may be an option. Very little information is available on feeding WDG, especially to dairy cattle. Klopfenstein and Stock (12) summarized several studies conducted by the authors on feeding WDG to feedlot cattle. Dry matter content of WDG averaged 31.4%. Nutrient composition of WDG is slightly different than DDG. The WDG fed in their research studies contained more starch and ethanol and less protein than typically found in DDG. The energy value for gain determined from feeding trials was 1.28 to 1.69 times greater for WDG than corn. No differences in protein efficiency were found between DDGS and WDG when fed to growing calves. As with any high moisture feed, the handling, storage, storage loss and transportation costs must be considered in the usage and economic value of WDG.

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