USES OF CORN COPRODUCTS IN BEEF AND DAIRY RATIONS

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USE OF CORN COPRODUCTS FOR BEEF CATTLE

Distillers grains **(DG)** are an excellent ruminant feedstuff. They are an excellent source both of energy and protein. In the production of alcohol, the starch, which is about two-thirds the composition of corn grain, is fermented to alcohol and CO_2. The remaining nutrients are then concentrated by a factor of three. Corn protein of 10% is concentrated to 30% and fat (oil) from 4 to 12%. Fiber is concentrated from 14 to 42%. The fiber is highly digestible and the fat has about three times the energy of starch. The protein is high in undegraded intake protein **(UIP)**.

The DG can be used as both a protein source and an energy source for growing cattle and for finishing cattle. For growing cattle, the value of the UIP is most important.

The DG are normally available for use in feedlot finishing diets in two forms, dried distillers and wet distillers grains. In general, there are two nutritional philosophies regarding their use in feedlot finishing diets. The DG can be fed at 6 to 15% of the diet dry matter **(DM)**, serving primarily as a source of supplemental protein. When fed at higher levels (greater than 15% of the diet DM), the byproduct's primary role is as a source of energy replacing corn grain. Other than DM content (wet DG, 35-45%; dried DG, 90-95%), the chemical composition of the two products is similar.

Dried DG is routinely fed as a supplemental protein source; however, the drying process appears to reduce the energy value of the DG. Ham et al. (1994) demonstrated a 9% improvement in feed efficiency when dried DG replaced 40% of the dry-rolled corn in finishing diets (Table 1). However, this improvement was only 50% of that observed when wet DG byproduct replaced a similar amount of dry-rolled corn. Drying cost significantly increases the commodity price for the DG. The dried DG is routinely priced relative to other supplemental protein sources like soybean meal. Therefore, when priced on an energy basis (relative to corn), the expected improvement in animal performance is not large enough to offset the increased ration cost associated with higher inclusion levels.

Wet DG are commonly fed at higher levels in the diet to supply both protein and energy to the animal. There are numerous advantages to using wet DG. For the dry-milling plant, the energy cost associated with drying the product can be significantly reduced or eliminated. This should allow for an overall increased energy yield for each bushel of corn processed. The major downside of using wet DG is transportation costs associated with the movement of water.

Experiments evaluating the use of wet DG in feedlot diets are available (DeHaan et al, 1983; Farlin, 1983; Firkins et al., 1985; Ham et al., 1994; Fanning et al., 1999; Larson et al., 1993; Lodge et al., 1997a; Trenkle, 1997a; Trenkle, 1997b). In the experiments with finishing cattle, the replacement of corn grain with wet DG consistently improved feed efficiency. Larson et al. (1993) replaced dry-rolled corn with 5.2, 12.6, or 40% (DM basis) wet DG (Table 2). With the first two levels of byproduct (5.2 and 12.6%), these researchers observed a 7% increase in feed efficiency above the basal dry-rolled corn diet. But, when the inclusion level was increased to 40% of the diet DM, the improvement in feed efficiency was 20% above the dry-rolled corn diet. In other published experiments (Ham et al., 1994; Fanning et al., 1999; Lodge et al., 1997a), the inclusion level of the wet distillers byproduct has been 30 to 40% of the diet DM. These experiments consistently suggest a 15 to 25% improvement in feed efficiency when 30 to 40% of the corn grain is replaced with wet DG.

Eleven experiments were summarized where wet DG was compared with corn as an energy source for finishing cattle (Table 3). The wet DG replaced 12.6 to 50% of the diet (corn). The data were summarized into three situations. First is the control diet based on dry-rolled corn. Second is when wet DG replaced corn at a low level in the diet (12.6 to 28%). The third situation is where wet DG replaced corn in the diet at 30 to 50% of dietary DM.

At the low level (average 17.4%) of wet DG feeding, the energy value was 152% that of corn. At the high level of feeding, the value decreased to 136% the value of corn. We can then calculate the value of the wet DG as 124% the value of corn when fed between 17.4 and 40% of the diet.

We believe there are very good explanations for the change in relative feeding values as wet DG increases in the diet. We believe the first increments fed (up to 17.4%) supply nutrients such as protein that may be of value to the cattle, but more importantly, reduce the acidosis that occurs in the control diet. The wet DG contains protein and fat which supply energy to the animal, but it does not contain the starch that leads to acidosis. Further, the fiber (hull) in the wet DG is highly digestible but adds fiber to the diet and reduces acidosis. So, the very high value of the wet DG (152%) at low level feeding is probably due to factors other than the strict energy value of the nutrients contained therein.

The value when fed above 17.4% of the diet is probably due to the high fat content of the wet DG and the high content of bypass protein. Fat has about three times the energy value of starch for cattle and bypass protein has about 30% more energy than starch. The value from feeding trials was determined to be 124% the value of corn. By calculating the theoretical energy value based on the bypass protein and fat contents, we estimate the energy value of wet DG to be 120% the value of corn. This calculation gives confidence in the value obtained from feeding trials.

Typical feedlot diets contain about 85% corn. The starch in the corn is the energy source used by the cattle. However, the starch is rapidly fermented by the rumen microorganisms to organic acids. The overproduction of the organic acids causes acidosis followed by reduced feed intake and reduced gains (Stock and Britton, 1993; Stock et al., 1995). Distillers byproducts have essentially all of the starch removed leaving protein, highly digestible fiber, and fat. The feeding of the byproducts appears to reduce acidosis and enhances feed efficiency.

There are at least three factors involved in the higher feeding value for distillers byproducts (protein, energy, acidosis). Based on the limited data available regarding the level of wet distillers byproduct in the diet, the economic value of the byproduct varies as the level fed in the diet changes. Also, as the level fed increases, more is fed per animal per day and more total byproduct would be fed. The precise relationship between level of byproduct in the diet and both the feeding value and economic value remains elusive.

Corn gluten feed is the other important corn milling byproduct. It is produced by the wet milling process and the byproduct is quite different from DG. Gluten feed contains the fiber from the corn but does not contain the fat or the zein protein (the high bypass protein) that is in the distillers grains. The gluten feed contains steep liquor, distillers solubles, corn bran, and germ meal in varying combinations.

Stock et al. (2000) have summarized the feeding values of two different gluten feeds for feedlot cattle. For the first product (Table 4), the feed efficiency (feed:gain ratio) was essentially equal between the control (corn) diets and the diets containing gluten feed. This suggests equal energy value for gluten feed and corn. Product B (Table 5) had dietary feed efficiencies 5% better than the control indicating higher energy value for the gluten feed than for the corn grain it replaced. Gluten feed, like DG, helps control acidosis. The gluten feed is actually less digestible than corn grain (Bierman et al., 1995) but has equal or higher apparent energy in feedlot diets because it controls acidosis.

Gluten feed is an excellent protein and energy supplement for growing calves or beef cows. It was used as a supplement for growing calves grazing corn stalks. In the range of 5 to 6 lb DM per day, gain was optimized and the supplemental needs for protein and phosphorus were met with gluten feed (Figure 1). Jordon et al. (2001b) have shown it to be a very cost effective supplement for growing calves.

USE OF CORN COPRODUCTS FOR DAIRY CATTLE

Coproducts of wet and dry milling, most notably DG and corn gluten feed **(CGF)**, have been used conservatively as forage and concentrate replacements in diets for lactating dairy cattle. Commonly, DG and CGF are fed at ≤20% of the dietary DM, but recent research indicates that substantially more can in fact be fed, especially for CGF. Maximizing the use of these corn coproducts in ruminant diets will become increasingly important as more ethanol plants are built in the near future.

An understanding of the chemical composition of these coproducts enables us to effectively position them in dairy formulations. Both contain 40 to 45% NDF which is highly digestible (6-8%/h digestion rate) due to low lignification and can therefore replace starch (10-30%/h digestion rate) and reduce the risk of ruminal acidosis (Allen and Grant, 2000). Due to their small particle size, both coproducts have <15% physically effective NDF and so do not stimulate much rumination (Clark and Armentano, 1993; Allen and Grant, 2000). Consequently, particle size of forage is a critical issue when either coproduct replaces forage. Major compositional differences between DG and CGF include lipid and protein fractions. Distillers grains, wet or dry, contain 30 to 35% CP, of which ~55% is ruminally undegradable protein **(RUP)**. In contrast, CGF contains 20 to 25% CP and only 25 to 30% RUP. The lipid content of DG is 10 to 15%, but <3% for CGF. These differences in physicochemical properties have positioned CGF primarily as a source of digestible NDF, whereas DG have been positioned as a source of RUP.

However, there is no reason why, with proper supplemention and forage combinations, that both coproducts could not serve as sources of RUP and energy. This section will focus on recent research aimed at optimizing the nutritional properties of these two coproducts and maximizing incorporation of them into diets for lactating dairy cows. For more comprehensive summaries of milk production responses to CGF or DG, refer to reviews by Chase (1991) and Schingoethe (2001).

Corn Gluten Feed for Dairy Cows

A summary of beef feedlot research (Stock et al., 2000) indicated that efficiency of gain was improved by 5.1% when diets contained 25 to 50% wet CGF (corn bran:steep liquor, 1:1 DM basis) were compared with dry-rolled corn. This positive response was likely due to reduced ruminal acidosis and increased DMI. Ruminal acidosis is a significant concern when feeding dairy cows as well because of the need for optimal ruminal fiber digestion in the presence of substantial amounts of starchy concentrate feeds. Corn bran is rapidly and extensively digested in the rumen. Consequently, the dilution of starch with NDF from CGF results in slower rates of fermentation, reduced acid load in the rumen per unit of fermentation time, and the ability to feed a highly digestible diet with low risk of ruminal acidosis.

Nonforage sources of fiber, such as CGF, do not stimulate rumination as effectively as forages. Therefore, it is necessary for dietary forage to have adequate particle length for normal rumination when replacing forage. Additionally, forage of longer particle length forms a digesta mat that more effectively filters and entangles smaller particles allowing greater time for fermentation in the rumen (Welch, 1982). Allen and Grant (2000) evaluated the effect of ruminal mat consistency on passage and digestion kinetics of wet CGF in dairy cattle. Table 6 summarizes the diets and key responses. Two diets were formulated to contain ~40% alfalfa, 24% wet CGF, plus a corn and soybean meal-based concentrate. One diet contained alfalfa silage and the other contained a 1:1 blend of alfalfa silage and coarsely chopped alfalfa hay of similar quality. Compared with the diet without added hay, the diet with added hay had 59% more long particles, a 37% increase in ruminal mat consistency, a 27% increase in rumination, equal NDF intake, but a 35% reduction in passage rate of CGF, an increase in ruminal NDF digestion of nearly 40%, and an increase in 4% fat-corrected milk (FCM) of 5.5%. Both diets contained 24% wet CGF, and this research points out the potential to manipulate passage and digestion of CGF to maximize NDF fermentation in the rumen. Though the research has not been conducted, presumably a similar response would be observed for DG since they have similar particle size and specific gravity as CGF. Fibrous coproducts can contribute more to highly digestible diets than previously thought if their passage and digestion kinetics are optimized, in addition to ensuring adequate physically effective NDF in the total diet.

One problem with the design of much previous research that evaluated CGF for dairy cows has been that diets were balanced for CP, but not metabolizable protein **(MP)**. Wet CGF contains twice as much CP as corn, but less MP (Krishnamoorthy et al., 1982; Stock et al., 2000). Thus, control diets containing corn grain, which use soybean meal to balance for CP, may contain CP concentrations similar to CGF diets, but these control diets also contain substantially greater amounts of MP. If MP is not adequate for diets containing CGF, erroneous conclusions may be made concerning their nutritional value. Several studies have indicated that ≤20% dietary wet

CGF is optimal for milk production (Droppo et al., 1982; Gunderson et al., 1988; Schroeder and Park, 1997). However, MP may have been limiting milk production rather than energy or effective NDF beyond 20% inclusion.

Recently, a series of studies (Boddugari et al., 2001) were conducted to develop a new wet CGF product based on ingredients from the wet milling process to enhance the MP content and to determine the maximal amount of this product that could be incorporated into the diet. The hypothesis was that a properly formulated wet CGF product could be fed in amounts much greater than currently practiced by the dairy industry. The wet corn milling feed product **(CMP)** developed was composed of corn bran, fermented corn extractives (steep liquor), corn germ meal, and additional sources of RUP to increase the MP content of the product. The CMP contained 23.1% CP, 43.0% RUP (% of CP), 13.7% ADF, 40.3% NDF, and 2.6% lipid (DM basis). For comparison, the nutrient profile of the wet CGF from the wet milling plant that provided the CMP is 22.5% CP, 30.0% RUP, 14.0% ADF, 43.0% NDF, and 2.5% lipid. Clearly, the major difference was an improvement in the RUP content of the CGF. In the first trial, four diets were evaluated that contained 54.3% forage with the CMP replacing either 0, 50, 75, or 100% of the concentrate. All of the diets containing CMP resulted in 7.8% lower DMI, equivalent milk production, and 13.6% greater efficiency of FCM production than the control diet. In a subsequent trial, the 100% concentrate replacement diet served as the control diet and 15, 30, or 45% of the forage was replaced with CMP. Production of 4% FCM and efficiency of FCM were unaffected by diet, but rumination decreased for the 30 and 45% replacement diets, although ruminal pH was unaffected. These two trials demonstrated, at least in short-term studies (4-wk periods), that up to 70% of the dietary DM could be comprised of CMP, which is far greater than previously published studies.

A final study (Boddugari et al., 2001) was designed to evaluate an optimal amount of CMP in the diet for early lactation cows. Cows were assigned, from day 1 to 63 of lactation, to either a control diet (no CMP) or a diet containing 40% CMP. The 40% level was chosen because the maximal effect on efficiency of FCM production was achieved at 50% concentrate replacement and 30% forage replacement in the previous trials. Table 7 summarizes the production responses to these diets. The diet containing the CMP resulted in a 21% greater efficiency of FCM production than the control diet. This series of studies showed that up to 70% of the diet can be replaced by a properly formulated wet CGF product, and that 40% of the dietary DM may be an optimal amount to feed. A key concept is that by correcting a deficiency in the coproduct feed (MP in this case), we were able to feed more and substantially increase the amount of energy the cow captured from digestible NDF, rather than starch, which should result in healthier, more productive cows long-term.

Distillers Grains for Dairy Cows

Most research has focused on DG as an alternative protein source to soybean meal (Owen and Larson, 1991 as an example). However, DG also is an excellent source of energy due to its high content of digestible NDF and lipid. In a recent review, Schingoethe (2001) suggested a maximum of 20% DG in the dietary DM fearing potential palatability problems and excessive protein consumption above this amount. However, a recent trial (Schingoethe et al., 1999) found that diets containing 31.2% wet corn DG versus a control diet (corn-soybean meal-based) resulted in a 13.6% increase in efficiency of energy-corrected milk production. The forage component of these diets contained ~63% corn silage and 37% alfalfa hay and resulted in a total dietary CP content of 21% and 22% elevation of serum urea levels. So, long-term considerations when feeding high levels of corn DG need to be: 1) proper ratio of forage sources to reduce dietary CP, and 2) supplemental sources of lysine if corn silage comprises the majority of the forage. It appears that total CP, and possibly lipid, in the diet will set upper limits on the amount of DG that can be incorporated into the ration, but 20 to 30% is feasible if the ration is properly formulated. Logical possibilities exist to combine DG and CGF to capitalize on the unique attributes of both coproducts (digestible NDF from CGF and RUP plus lipid from DG) to create products that would allow higher levels of inclusion in the diet and increase efficiency of milk production. In addition, there is evidence that the lipid in corn DG is effective at increasing the unsaturated to saturated fatty acid ratio in milk fat (Schingoethe et al., 1999).

Two major questions concerning use of DG by dairy cows are: 1) is there a difference between wet and dry DG, and 2) does source of grain for the fermentation impact the nutritive value of the DG. One study (Al-Suwaiegh et al., 1999) has compared wet versus dry DG from the fermentation of either 100% corn or 100% sorghum. All the diets contained 50% of a 1:1 mixture of alfalfa and corn silages and 15% DG. Chemical composition of the corn and sorghum DG were similar. Efficiency of FCM production was similar for cows fed either corn or sorghum DG in the wet or dry form (Table 8). Since efficiency was the same, whether wet or dry, the form of the DG is primarily a function of what works best for the farm given the feed storage and handling capabilities. The production of 4% FCM tended to be reduced when cows were fed DG from sorghum versus corn. The impact of grain source on the quality of DG and its effect on long-term milk production is unknown. Because we know that wet and dry DG are similar, a study needs to be conducted that compares either wet or dry DG fed continuously during early lactation.

Feeding DG and CGF to Dairy Cows: Bottom Line

Unquestionably, DG and CGF are excellent sources of digestible NDF, RUP, and lipid for dairy cattle diets. Particularly for CGF, much more (at least 2x) can be incorporated into diets than has been previously recommended. We need to consider the nutrient profile of these coproducts, and supplement to correct any nutrient deficiencies, either to the diet or by creatively combining various milling coproducts. In addition, we need to manipulate the physical as well as the chemical properties of the forage component of the diet to maximize the use of these coproducts. There is tremendous potential to combine corn milling coproducts that will allow maximal replacement of forage and concentrate. This approach will likely become more important as more ethanol plants are built over the next several years. The traditional paradigm in feeding dairy cattle has been to maximize the amount of forage in the diet which necessitates an exquisite focus on forage quality. However, when high quality forage is expensive or in limited supply, or in areas where coproducts are abundant, the paradigm needs to shift to maximizing use of the byproduct and ensuring that the forage meets the minimal requirements for physically effective NDF. Both DG and CGF products should be effective at providing a consistent quality, highly digestible diet for lactating dairy cows.

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Table 1. Energy Value of Wet vs Dry Distillers Grains

	Control	Wet	Low[a]	Medium[a]	High[a]
Daily feed, lb	24.2[bc]	23.5[b]	25.3[c]	25.0[c]	25.9[c]
Daily gain, lb	3.23[b]	3.71[c]	3.66[c]	3.71[c]	3.76[c]
Feed/gain	7.69[b]	6.33[c]	6.94[d]	6.76[d]	6.90[d]
Improvement:					
Diet		21.5		11.9 (ave.)	
Distillers vs corn		53.8		29.8	

[a]Level of ADIN, 9.7, 17.5 and 28.8%.
[b,c,d]Means in same row with different superscripts differ ($P < 0.05$).

Table 2. Effect of Wet Distillers Grains Level on Finishing Performance of Yearlings and Calves

	DG level, % of diet DM[a]			
Item	0	5.2	12.6	40.0
Daily feed, lb				
Yearlings[b]	25.21	24.64	24.05	21.30
Calves[b]	18.52	19.23	18.55	17.40
Daily gain, lb				
Yearlings[c]	3.61	3.76	3.85	3.85
Calves[b]	2.86	3.06	3.08	3.21
Feed/gain[d]				
Yearlings[e]	6.94	6.62	6.33	5.78
Calves[b]	6.45	6.33	6.10	5.65

[a]Wet grains:thin stillage (fed ratio), yearlings = 1.67:1; calves = 1.81:1, DM basis.
[b]Byproduct level, linear ($P < 0.01$).
[c]Byproduct level, linear ($P < 0.10$); quadratic ($P < 0.10$).
[d]Feed/gain analyzed as gain/feed. Feed/gain is reciprocal of gain/feed.
[e]Byproduct level, linear ($P < 0.10$).

Table 3. Influence of Level in Diet on Value of Wet Distillers Grains Plus Solubles in Feedlot Diets

	Wet DG level in diet dry matter		
Experiment	0	12.6 - 28%	30 - 50%
Trenkle, 1997a	.154[a]	.183 (20)[b] 194%[c]	.176 (40)[b] 137%[c]
Trenkle, 1997a	.154		.176 (40) 136%
Trenkle, 1997b	.164	.207 (16) 126%	.168 (40) 102%
Trenkle, 1997b	.164	.171 (28) 114%	
Firkins et al., 1985	.155	.156 (25) 101%	.171 (50) 121%
Larson et al., 1993	.144	.158 (12.6) 177%	.173 (40) 150%
Larson et al., 1993	.155	.164 (12.6) 164%	.177 (40) 135%
Ham et al., 1994	.133		.158 (40) 147%
Fanning et al., 1999	.154		.172 (30) 147%
Means		152% (17.4)	136% (40)
Value 17.4 to 40			124%

[a]Feed efficiency.
[b]Level in diet dry matter.
[c]Value relative to corn.

Table 4. Energy Value of WCGF-A[a] for Beef Finishing Cattle

Reference	Amount in diet, % of DM	Number of replications	Relative feed:gain[b]
Bierman (1995)	41.5	4	1.04
Ham et al. (1995); Trial 1	35.0	4	1.06
	70.0	4	1.06
Ham et al. (1995); Trial 2	17.5	4	1.06
	35.0	4	.97
	52.5	4	1.01
	70.0	4	.97
	87.5	4	1.01
Krehbiel et al. (1995)	35.0	2[c]	.96
Lodge et al. (1997b)	40.0	2[c]	1.00
McCoy et al. (1998); Trial 1	45.0	12	.98
McCoy et al. (1998); Trial 2	45.0	16	.99
Average, all levels	47.6	---	1.00
Average, 20 to 60% of diet DM	43.0	---	.997

[a]WCGF-A = wet corn gluten feed, 40% DM content.
[b]Calculated as feed/gain of control diet divided by feed/gain of treatment diet.
[c]Individually fed cattle trial. Treatment assigned two pen replications for calculation purposes.

Table 5. Energy Value of WCGF-B[a] for Beef Finishing Cattle

Reference	Amount in diet, % of DM	Number of replications	Relative feed;gain[b]
Richards et al. (1996)	44.0	4	.89
	42.4	4	.91
	86.6	4	.91
Scott et al. (1997a)	10.4	4	1.02
	20.8	4	.99
	38.2	4	.97
Scott et al. (1997b)	30.0	2[c]	.90
	60.0	2[c]	.92
Herold et al. (1998)	22.5	4	.99
Richards et al. (1998)	25.0	8	.97
	50.0	4	.96
Average, all levels	37.3	---	.951
Average, 20 to 60% of diet DM	34.8	---	.949

[a]WCGF-B = wet corn gluten feed, 60% DM content.
[b]Calculated as feed/gain of control diet divided by feed/gain of treatment diet.
[c]Individually fed cattle trial. Treatment assigned two pen replications for calculation purposes.

Table 6. Ruminal passage and digestion of wet corn gluten feed (CGF).

Item	CGF	CGF + Hay
Ingredients, % of DM		
Alfalfa silage	39.8	19.9
Alfalfa hay	—	18.8
Wet CGF	24.4	24.4
Concentrate mix	35.8	36.9
% Particles ≥9.5 mm screen	7.3	11.6
NDF intake, % of BW	1.4	1.4
Ruminal mat consistency,		
ascension rate, cm/sec	0.26[a]	0.19[b]
Passage rate of CGF, %/h	6.40[a]	4.20[b]
Apparent extent of ruminal NDF digestion, %	32.4[b]	44.8[a]
Rumination, min/kg NDF intake	46.5[b]	59.2[a]
4% Fat-corrected milk, kg/d	27.9	29.4

[ab]Means within row with unlike superscript differ ($P < 0.10$).

Table 7. Performance of dairy cows fed 40% wet corn milling feed product (CMP) from day 1 to 63 of lactation.

Item	0% CMP	40% CMP
DMI, % of BW	4.27[a]	4.06[b]
NDF intake, % of BW	1.16[b]	1.40[a]
4% FCM, kg/d	38.5[b]	44.6[a]
FCM/DMI, kg/kg	1.47[b]	1.79[a]
Body condition score	2.93	3.00

[ab]Means within row with unlike superscripts differ ($P < 0.05$).

Table 8. Wet versus dry distillers grains (DG) from corn or sorghum fed at 15% of ration DM.

	Corn DG		Sorghum DG	
Item	Dry	Wet	Dry	Wet
DMI, % of BW	3.9	4.0	4.1	4.0
4% FCM, kg/d	33.3	33.0	31.9	31.3
FCM/DMI, kg/kg	1.3	1.3	1.3	1.2
Milk fat, %	3.7	3.6	3.5	3.5
Milk protein, %	3.4	3.3	3.2	3.2