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Value and Use of Corn Milling By-Products
In the Cow Herd

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Introduction

There are many different grain by-products available for cow/calf producers to use in rations. Grain by-products such as wheat midds, soy hulls, and cottonseed hulls have been available for many years and have been used effectively in cow diets and supplements. More recent grain by-products have come from the production of fructose (wet or dry corn gluten feed) or ethanol (wet or dry distillers grains). This paper will focus on by-product of corn milling industry. This paper will discuss the wet and dry milling process, product quality, nutrient quality, and research on use by beef cattle.

Dry Milling Industry

In the dry milling industry, the feed product(s) that are produced are distillers grains, distillers grain + solubles, and distillers solubles. Depending on the plant and whether producing wet or dry feed, the relative amounts of distillers grains and distillers solubles that are mixed together vary. However, our current estimates are that wet distillers grains + solubles are approximately 65% distillers grain. It is always a fair assumption that distillers grains will contain some solubles. The dry milling process is relatively simple. Corn (or any starch sources) is ground, fermented, and the starch converted to ethanol and CO₂. The primary goal of dry milling is the production of fuel ethanol. In a typical system, cereal grain (generally corn or sorghum in the U.S.) is slurried, heated to gelatinize the starch, and cooled. Yeast is added and the grain is allowed to ferment for several days. As a result of the fermentation, starch is converted to alcohol and carbon dioxide. This mixture can then be distilled to remove the alcohol, with the remaining material referred to as whole stillage, which can be screened or centrifuged to yield wet distillers grains and thin stillage or distillers solubles. Alternatively, the grains may be separated prior to distillation, with the end products being similar. Distillers solubles can be dried to form condensed distillers solubles. The condensed distillers solubles can be added to the wet grains in varying proportions to yield a product known as wet distillers grains plus solubles. Approximately one-third of the DM remains as the feed product following starch fermentation. As a result of this process, the nutrient content of the remaining residue after the extraction of the starch are increased 3-fold because most grains contain approximately two-thirds starch. As an example, corn grain is typically 4% oil or fat, wet or dry distillers grains are about 12% fat (dry matter basis). Distillers grains can also be marketed as a dry product (87 to 91% DM), with or without additional of the distillers solubles.

Wet Milling Industry

The wet milling industry is more complex. The corn kernel is divided into more components that in turn, increases the dollar value for marketing. For example, the oil is extracted from the corn and sold as corn oil. The importance of understanding the process is that the resulting feed products from these two industries are quite different based on how they are produced. The wet milling industry also has more restrictions in terms of grain quality and is limited to corn. The primary goal of wet milling corn is fractionation of the kernel. The distinct advantage over dry milling is that it yields a corn starch slurry of high purity. In addition, a number of products could potentially be for human use. Only #1 or #2 grade corn can be used in the United States. In the wet milling process, shelled corn is initially screened to remove crop residues, fines, and broken kernels. The cleaned grain is then steeped in a dilute sulfur dioxide solution for 40 to 48 h. Steeping softens the grain to facilitate grinding, removes soluble materials, and makes the starch fraction more available by disrupting the surrounding protein matrix. The kernel is then fractionated using a combination of grinding, differential separation and centrifugation. The various fractions isolated as an approximate percentage of the original corn grain include starch (68.0%), bran (12.0%), germ (7.5%), steep liquor (6.5%), gluten (5.6%), with the remaining (.04%) representing losses of volatile materials or other inefficiencies. These proportions will vary with changes in the profile of the original grain. Isolating starch, which comprises about two thirds of the kernel is the principal objective of the separation process. Starch and gluten are isolated from the other kernel fractions through steeping, grinding, and density separation. The starch fraction can be sold as dried corn starch, corn syrup, or high-fructose sweetener. Additionally, isolate starch can be converted to dextrose, which can serve as a carbon source for a number of microbial fermentations. Ethanol can be produced by yeast fermentation of dextrose. Distillers solubles are the byproduct of fuel ethanol production in the wet milling process. This product contains yeast cells and residual sugars. Distillers solubles arising from the wet milling process differ from those produced by dry milling. Because the germ fraction is separated in the wet milling process, and not in the dry milling process, wet milling distillers solubles contain low levels of fat. Corn gluten feed is comprised of steep liquor and corn bran; but may also contain germ meal, partial corn kernels and other ingredients.

Variation With Byproducts

The primary objective of the dry milling process is the produce fuel ethanol. Because the resulting feedstuffs are secondary, they often can be quite variable in their nutrient content. A number of factors can impact the nutrient profile of distillers grains, including moisture content, grain selection, the ratio of grains and distillers solubles included in the product, continuous vs batch fermentation, as well as drying temperature and duration.

Moisture variation may pose the biggest challenge in managing wet by-products. When 18 samples of dry distillers grains plus solubles from ten dry milling plants in South Dakota and Minnesota from 1997 to 1999 were analyzed, samples averaged 88.3% DM, 28.2% CP, 8.2% fat, and 42.1% NDF. Coefficients of variation for across-plant means ranged from 1.7% for DM to 14.3% for NDF. Within a plant, the highest coefficient of variation for dry distillers grains plus solubles dry matter was 2.0%. This is in contrast to the

moisture consistency of wet distillers grain plus solubles which may have a 10% coefficient of variation within a plant. Compared to distillers grains, condensed distillers solubles contain more CP and lipid, with less NDF. The relative inconsistency of wet distillers grains plus solubles may be attributable to more variation in the amount of distillers solubles that wet grains can accommodate as compared to dry grains.

In addition to the variation attributable to grain source, the nutrient content of the end product will depend on the ratio of grains and solubles in the wet or dry mixture. Plants that dry the grains prior to adding solubles are capable of getting more solubles to stay in the mixture. However, maintaining separate products to dry the grains adds expense; therefore, the wet products are often combined resulting in a lower proportion of solubles in the resulting dry distillers grains plus solubles.

In traditional dry milling, not all the solubles can be held by the wet distillers grains; therefore, some solubles must be marketed separately as condensed distillers solubles, also known as corn syrup. Therefore, it is probably important to remember to get a feed analysis, that includes moisture content and other nutrients. However, most of the variation is in the amount of moisture in the wet product.

Feed Composition

Distillers Grains

Corn is 2/3 starch and the starch is removed during alcohol production. The remaining nutrients are increased three-fold compared to corn; therefore, distillers grains contains 28 to 30 % crude protein, 35% of the protein is degraded in the rumen (DIP) and 65% of the protein by-passes the rumen (UIP), 11 to 12% fat (oil), 40 to 45% NDF and .8 to .9% phosphorus.

Distillers grains are excellent sources of protein, mostly undegraded protein (by-pass protein or UIP). Excessive heating of protein sources can result in the formation of acid detergent insoluble nitrogen which renders protein unavailable to the animal. This has been a concern with products of the dry milling industry. However, in trials using growing calves fed either wet or dry distillers in forage diets, performance was not different.

As an energy source in feedlot diets, the energy value is 120 to 150% the value of dry rolled corn. The higher values appear to be due to acidosis control. In addition, recent research by Loy et. al (2004) suggests that both the wet and dry distillers grains have an energy value 120 to 127% of that of dry rolled corn in forage diets. As a commodity, distillers grains can be fed as a protein or phosphorus supplement or as an energy/fat supplement. Degradable protein supplementation appears not necessary with distillers grains feeding if sufficient metabolizable protein is fed. NDF is neutral detergent fiber and notice that it is 3 times higher in distillers grains than in corn grain. In fact the NDF content of distillers is much like that of a forage. In addition, because the starch is removed in the process, distillers is digested in very much the same way that forages are digested in the rumen. This basically means that the rumen microbial population doesn't change much when distillers is added to high forage diets because the microbes that digest distillers also digest

forage. The result is a high energy fiber source, distillers grains, that has no negative associate effects on fiber digestion. These characteristic makes distillers a very attractive supplement in cow diets. Dry distillers is typically 90% dry matter and wet distillers will be between 35% to 50% dry matter depending on the plant.

Corn Gluten Feed

Again, corn gluten feed is a by-product of the wet milling process. Wet or dry corn gluten feed is an excellent feed for both the feedlot and cow/calf industry. In the process, the starch is removed and commonly made into sweetener (fructose). Like distillers, the NDF content is much higher than corn. Therefore, corn gluten feed is digested similar to distillers and forage in the rumen. The result is a high energy fiber source, corn gluten feed, that has no negative associate effects on fiber digestion. Corn gluten feed is a good source of energy, protein, and phosphorus.

Corn gluten feed is between 19 to 24% crude protein, 80% of the protein is degraded in the rumen (DIP) and 20% by-pass rumen degradation (UIP). This by-product is also high in phosphorus (.9-.11%) and sulfur (.47%). Corn gluten feed is about 3.9% fat. Dry corn gluten feed is typically 90% dry matter and wet gluten is between 42 to 44% dry matter.

Wet corn gluten feed is similar to or has a higher energy (100 - 110%) content than corn grain depending on the plant and how much steep is added. Dry corn gluten feed has a lower energy content than wet, meaning that in drying process something happens that results in a reduction in energy. Corn germ is the fraction containing the majority of the oil present in the original kernel. Whole germ contains 48% oil, 13% CP, and 12% starch. Corn germ meal is the feed product resulting from the extraction of the oil from the germ fraction. Solvent-extracted germ meal may be around 10% DM, and contain 25% CP and 1.5% oil. Germ meal may also be added to corn gluten feed.

Beef Cows and Developing Heifers

By-products, particularly dry distillers grain and dry corn gluten feed, may have benefits to cow-calf producers. Cows are often supplemented with protein but also may require energy through the winter, during early spring months following calving, or for replacement heifers. When forage quality is poor (winter) or quantity is limiting (drought), byproducts may fit. These feeds also work well in cornstalk grazing situations.

Loy et al. (2004) concluded that dry corn gluten feed decreases feed costs compared to conventional hay feeding when fed over the winter for developing heifers on a commercial, Nebraska ranch in the sandhills. In this study, a treatment system was compared to their conventional management using over 550 heifers in each group across two years. The treatment system used only grazed winter forage and dry corn gluten feed supplementation compared to some winter grazing, with hay and protein supplementation. Little differences were observed in developing heifer performance by design. The major implications were reduced costs (\$6.71 per heifer) through the winter, while maintaining excellent performance and reproduction.

An experiment was conducted with 120 crossbred heifers to determine the value of dry distillers grains in high-forage diets and to evaluate the effect of supplementing daily compare to three times weekly (Loy et al., 2003). Heifers were fed to consume grass hay ad libitum and supplemented with dry distillers grain, dry rolled corn, or dry rolled corn with corn gluten meal. Corn gluten meal is a high protein feed that is much different than corn gluten feed. Supplements were fed at two levels and offered either daily or three times per week in equal proportions. Heifers supplemented daily ate more hay, gained faster (1.37 vs. 1.24 lb/day), but were not more efficient than those supplemented on alternate days. The calculated net energy values for dry distillers grains were 27% greater than dry rolled corn.

Dry distillers grain contain approximately 65% rumen undegradable protein (UIP; % of CP), consequently forage based diets that include dry distillers grains fed as an energy source are commonly deficient in rumen degradable protein (DIP) but contain excess metabolizable protein (MP). Cattle convert excess MP to urea which is potentially recycled to the rumen and can serve as a source of DIP. Many factors influence urea recycling, and the amount of the urea that is recycled when dry distillers grain is included in a forage-based diet is not known. The objective of trials at the University of Nebraska has been to determine if added DIP (i.e. urea) is required in forage-based diets where dry distillers grains were included at levels in excess of the MP requirement.

Two experiments evaluated supplemental DIP requirements when dry distillers grains were fed as an energy source in forage-based diets (Stalker et al., 2004). Diets were formulated to be greater than 100 g/day deficient in DIP but with excess metabolizable protein. In both experiments, no response in performance was observed when urea was added to the diet. Sufficient urea was recycled to correct the DIP deficiency. These studies indicate adding urea to meet the DIP requirement is not necessary when dry distillers grains are fed as an energy source in forage based diets in an amount that metabolizable protein is in excess.

Thirty heifers grazing smooth bromegrass were individually supplemented with 0, 1.0, 2.1, 3.1, or 4.2 lb/day/head of dry distillers grains dry matter for 84 days to determine effects of dry distillers grains supplementation on average daily gain (ADG) and forage intake and to determine the value of dry distillers grains in grazing enterprises (MacDonald et al, 2004). Forage intake was estimated using the 1996 NRC model. Supplementation of dry distillers grains resulted in a linear increase in ADG and decreased estimated forage intake. The dry distillers grains may be an attractive supplement in a grazing situation, when forage prices are high or forage supply is limited. More research in this area is currently underway.

A growing concern among U.S. livestock feeding industries is phosphorus management. As indicated earlier, by-products of the corn milling industries are generally high in phosphorus. The average P content in dry distillers was 0.89% of DM. High levels of phosphorus may be useful in supplementing cattle grazing forages, which generally contain less than 0.20% phosphorus (NRC, 1996). For example, the NRC (1996) indicates a phosphorus requirement of 20 g per d for pregnant heifers in late gestation. Supplementing dry distillers grains at 5.1 lb per head per day would supply that phosphorus need, in addition

to energy and protein. In a grazing situation and depending on the forage and level of intake, if 75% of the phosphorus requirement were obtained from forage only 1.1 lb of dry distillers grains would be needed to meet phosphorus requirement. This would eliminate the need for inorganic P supplementation, which often is the most expensive ingredient in commercial mineral mixes. Management of excess phosphorus found in by-products is an issue that warrants further consideration in the feedlot, but may be an asset in a cow/calf grazing situation.

Distillers and corn gluten feed are relatively high in sulfur. Our current recommendation is to maintain dietary sulfur at or below 0.4% of the diet dry matter. In most beef cow diets, sulfur is not a concern. If the product is fed, then it is important to spread it out so that all animals have an opportunity to consume the ration. The sulfur content of distillers and gluten feed is between .4% and .47%. If total intake is not limited, usually these grain by-products would only make up 10 to 30 percent of the diet. In limit-fed high grain diets in drought situation, pay close attention to total sulfur content of the ration. Also, care must be taken in situations where the sulfur content of the water is high.

Because of the high fat content of distillers grains, care must be taken not to get the fat content of the diet too high. Fat in high forage diet can reduce fiber digestion. Total fat content of the diet should not exceed 5% of the ration on a dry matter basis.

Summary

Corn byproducts can be used for either protein supplementation or energy supplementation of backgrounding or heifer/cow diets. Considerable difference exists between wet milling (corn gluten feed) and dry milling (distillers grains) byproducts in terms of nutritional value, primarily based on the process. The energy value of wet distillers grains is 125% or more the energy value of corn. Wet corn gluten feed varies from equal to or slightly higher (110%) energy than corn, depending on the amount of steep liquor. When dried, the energy value of gluten feed is reduced. Both distillers grains and corn gluten feed are good sources of protein. Distillers grains are high in UIP and makes it an excellent feed for young, growing cattle and lactating cows. Corn gluten feed as a protein source is high in DIP and is a good source of nitrogen for the rumen microbes. Dried distillers grains and dry corn gluten feed may fit well in backgrounding diets for young light calves or in cow-calf operations for either protein or energy. Because supply of corn milling products will likely increase in the future, more can and should be used by beef producers if priced competitively. Feeding wet by-products requires extra management and beef operations to be located in close proximity to plants due to the cost of transporting water.

When direct comparisons between wet and dry by-products have been made, the energy value of wet products has generally proven superior, with little difference noted in protein quality. Evaluating by-products solely as energy or protein sources is somewhat difficult, in that they are often good sources of both. In addition, by-products generally supply both DIP and UIP, may reduce or eliminate negative associative effects, alleviate acidosis, or have positive associative effects that complicate comparisons to more traditional

energy and protein sources.

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Table 1. Nutrient composition of selected corn milling byproducts.

Feedstuff: ^a	DRC ^b	WCGF-A	WCGF-B	DDGS ^c	WDGS ^c	CCDS ^c	MWDGS	Steep ^d
DM, %	90	44.7	60.0	90.4	34.9	35.5	45-50	49.4(49.0) ^e
SD	0.88	0.89	0.05	1.7	3.6	1.4	NA	1.0(0.58) ^e
CP, % of DM	9.8	19.5	24.0	33.9	31.0	23.8	NA	35.1
SD	1.1	0.63	0.51	1.3	0.9	1.5	NA	1.1
RUP, % of CP	60	20	20	65	65	65	NA	20
P, % of DM	0.32	0.66	0.99	0.51	0.84	1.72	NA	1.92
SD	0.04	0.03	0.04	0.08	0.06	0.27	NA	0.11
TDN, % of DM	90.0	90.0	94.5	101	112	112	NA	113
Neg, Mcal/lb	0.70	0.70	0.74	0.78	0.87	0.87	NA	0.88

^aDRC=dry rolled corn with NRC (1996) values, WCGF=wet corn gluten feed from two plants, DDGS=dried distillers grains + solubles, WDGS=wet distillers grains + solubles, CCDS=condensed corn distillers solubles (corn syrup), MWDGS=modified wet distillers grains + solubles, steep is steep liquor from wet milling plants, DM=dry matter, SD=standard deviation, CP=crude protein, RUP=rumen undegradable protein, TDN=total digestible nutrients, NA=not available.

^bDRC values based on NRC (1996) with approximately 3500 samples

^cValues are from spring, 2003 from only one plant in Nebraska that produces DDGS, WDGS, and CCDS with standard deviation based on weekly composites.

^dDM values are present variation from daily composites for a 60-day period. Other nutrients are based on monthly composites for 2002 and half of 2003.

^eValues in parentheses are monthly composites for 2003 from one plant in Nebraska, with assumptions that it is a mixture of steep and distillers solubles.

Table 2. Nutrient content of feeds^a.

Feed	% CP	% DIP	% UIP	TDN
Corn	9.8	45	55	90
Distillers grain	30.0	35	65	100 - 110
Corn gluten feed	23.8	80	20	90-98
Wheat midds	18.4	77	23	83

^aValues from 1996 NRC.

Table 3. Weight, body condition, and conception rates of heifers in two systems.¹

Item	Control	Treatment
	<u>Year One</u>	
Pre-calving BW change, lb	100.0	98.3
Pre-calving BCS change	-0.16 ^a	-0.08 ^b
Post-calving BW change, lb	-100.1	-98.3
Post-calving BCS change	0.16	0.28
	<u>Year Two</u>	
Pre-calving BW change, lb	-5.1 ^a	12.3 ^b
Pre-calving BCS change	-0.75 ^a	-0.48 ^b
Post-calving BW change, lb	2.82	0.04
Post-calving BCS change	-0.30 ^a	-0.57 ^b
Pregnancy rate, % ²	96.1	96.4

¹Control=winter grazing with hay and protein supplementation, Treatment=only winter grazing with dry corn gluten feed supplementation, BW=body weight, and BCS=body condition score. Data taken from Loy et al. (2004).

²Percentage pregnant with second calf.

^{a,b}Unlike superscripts within a row differ, $P < 0.05$.

Table 4. Performance of animals fed diets where 0, 33, 100 or 133% of the NRC predicted degradable intake protein requirement was met with supplemental urea (Stalker).

Item	Diet				SEM
	0	33	100	133	
Initial BW, lb	611	611	617	614	11
Final BW, lb	694	697	702	702	15
ADG, lb	1.06	1.06	1.01	1.04	.07
Total DMI, lb	11.3	11.4	11.5	11.4	.2
Feed: Gain	11.1	11.8	11.7	11.7	.09

Table 5. Diet evaluation using the NRC (1996) model 0, 33, 100, 133% of the NRC predicted degradable intake protein requirement was met with supplemental urea (Stalker).

Input	Diet			
	0	33	100	133
TDN, %	70	70	69	69
CP, %	126	13.6	15.6	16.6
NE adjust, %	100	98	101	106
<u>Outputs</u>				
DIP balance, g/da	-124	-66	54	112
MP balance, g/da	120	127	108	97
