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# Utilization of Corn Co-Products in the Beef Industry

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# FEEDING OF CORN MILLING CO-PRODUCTS TO BEEF CATTLE

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## INTRODUCTION

Corn milling co-products are expected to increase dramatically in supply. Two primary types of milling processes currently exist, resulting in quite different feed products. The dry milling process produces distillers grains plus solubles, and the wet milling process produces corn gluten feed. These feeds can be marketed as wet feed, or they can be dried and marketed as either dry corn gluten feed or dry distillers grains with or without solubles. For the purposes of this article, only wet corn gluten feed (WCGF) and wet distillers grains plus solubles (WDGS) will be discussed. The majority of plant expansions are dry milling plants that produce WDGS; however, an increase in supply of WCGF is also expected. Therefore, these feeds may be very attractive for beef producers to use as an energy source. This article will focus on the production, composition of these feeds, energy values, and economics of using WDGS. Some other management issues will be discussed as well including grain processing when these co-products are used in feedlot diets, roughage level when these co-products are used, and feeding combinations of WDGS and WCGF. Forage fed situations will be covered with dried co-products as this will be the most common application for both energy and protein supplementation in many forage feeding situations.

## WET MILLING

Wet milling is a process that requires use of high quality (No. 2 or better) corn that results in numerous products for human use. During this process (Figure 1), corn is "steeped" and the kernel components are separated into corn bran, starch, corn gluten meal (protein), germ, and soluble components. Wet corn gluten feed usually consists of corn bran and steep, with germ meal added if the plant has those capabilities. For a more complete review of the wet milling process, the reader is referred to Blanchard (1992). Dry corn gluten feed contains less energy than wet corn gluten feed (Ham et al., 1995) when fed at high levels in finishing diets. Wet corn gluten feed can vary depending on the plant capabilities. Steep liquor contains more energy than corn bran or germ meal as well as protein (Scott et al., 1997). Therefore, plants that apply more steep to corn bran or germ meal will produce WCGF that is higher in CP and energy.

WCGF contains 16 to 23% CP, which is approximately 80% ruminally degradable (degradable intake protein, DIP) protein used by microbes. During wet milling, corn gluten meal is removed and marketed in higher value markets. Corn gluten meal should not be confused with WCGF, as corn gluten meal contains approximately 60% CP which is only 40% DIP or 60% bypass protein (undegradable intake protein, UIP). Distinct differences exist for WCGF, even within companies, due to plant-to-plant variation. Stock et al., (1999) divided WCGF into two main categories, depending on the ratio of steep to bran. Because of differences in the amount of steep added, WCGF has approximately 101  to 115% the energy value of dry-rolled corn when fed at levels of 20 to 60% of diet DM (Stock et al., 1999). Higher energy (and protein) is associated with greater amounts of steep in WCGF.

## DRY MILLING

In the dry milling industry, the feed product(s) that are produced are distillers grains, distillers grains + solubles, and distillers solubles. Depending on the plant and whether it is producing wet or dry feed, the relative amounts of distillers grains and distillers solubles mixed together varies. However, our current estimates are that wet distillers grains + solubles are approximately 65% distillers grains and 35% distillers solubles (DM basis). Distillers grains (+ solubles) will hereby be referred to as either WDGS (wet distillers grains) or DDGS (dry distillers grains).

**Figure 1** – Schematic of the wet milling industry resulting in wet or dry corn gluten feed.

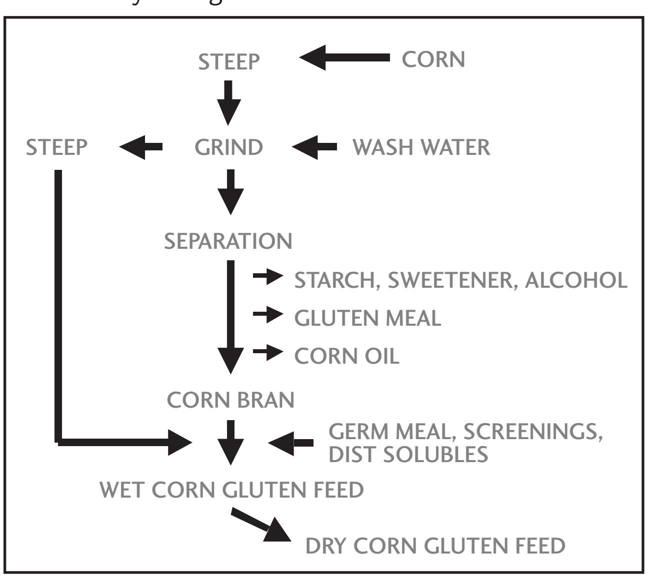



**Figure 2** – Schematic of the dry milling industry with the feed products produced.

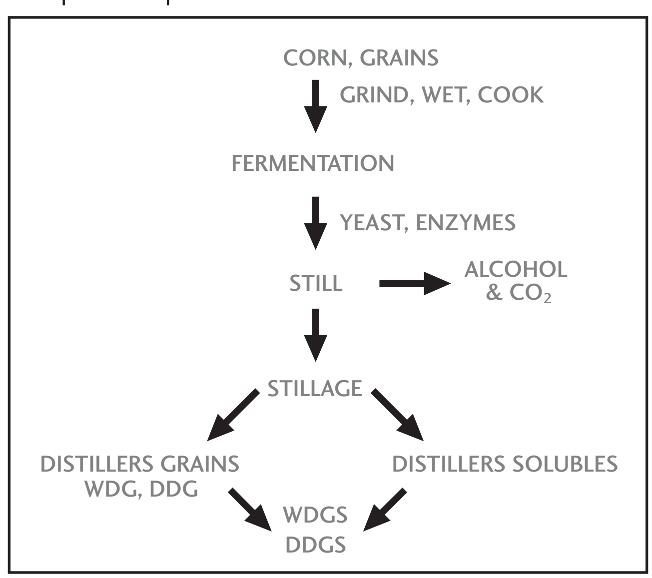


**Table 1** – Energy value of wet vs dry distillers grains in finishing diets when fed at 40% of diet DM.

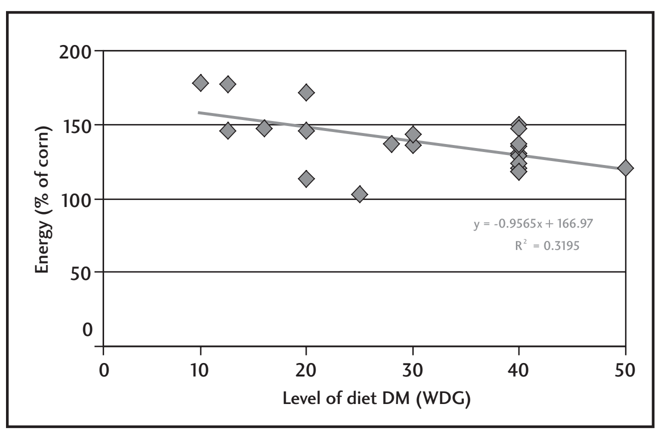
| | Control | WDGS | Low[a] | Medium[a] | High[a] |
|---|---|---|---|---|---|
| DMI, lb/d | 24.2 b[bc] | 23.56[b] | 25.3[c] | 25.0[a] | 25.9[a] |
| ADG, lb | 3.23[b] | 3.71[c] | 3.66[c] | 3.71[c] | 3.76[c] |
| Feed/gain | 7.69[b] | 6.33[c] | 6.94[d] | 6.76[d] | 6.90[d] |
| Improvement: | | | | | |
| Diet | -- | 21.5 | …………11.9 (ave.)……..….. | | |
| Distillers vs corn | -- | 53.8 | …………….29.8……………. | | |

[a] Level of ADIN, 9.7, 17.5 and 28.8% in DDGS.
[b,c,d] Means in same row with different superscripts differ (P<.05).

Our assumption is that the distillers grains will contain some solubles, but this can vary from plant to plant. The dry milling ethanol process (Figure 2) is relatively simple where corn (or another starch source) is ground, fermented, and the starch converted to ethanol and $CO_2$. Approximately 1/3 of the DM remains as the feed product following starch fermentation, assuming that starch source is approximately 2/3 starch. 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 WDGS or DDGS will contain approximately 12% oil. The wet milling industry is more complex and the corn kernel is divided into more components for higher value marketing. For example, the oil is extracted and sold in the wet milling industry as is the corn gluten meal, a protein supplement that contains a large amount of bypass protein, or UIP, commonly marketed to the dairy, poultry, or pet industries. 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 majority of the research on distillers grains as an energy source has been conducted on finishing cattle. Feeding wet distillers grains (WDGS) results in better performance than dry distillers grains (DDGS; Table 1). Experiments evaluating the use of wet distillers co-products in ruminant diets are available (DeHaan et al, 1982; Farlin, 1981; Firkins et al., 1985; Fanning et al., 1999; Larson et al., 1993; Trenkle, 1997a; Trenkle, 1997b; Vander Pol et al., 2005a). In the experiments with finishing cattle, the replacement of corn grain with wet distillers co-product consistently improved feed efficiency. Figure 3 summarizes these studies conducted on wet distillers grains with energy value expressed relative to corn. The energy value is consistently higher than corn. These experiments suggest a 15 to 25% improvement in feed efficiency when 30 to 40% of the corn grain is replaced with wet distillers co-product . The energy value at medium levels (12 to 28%, average of 17% of diet DM) is approximately 140 to 150% the energy of corn. When higher levels are

**Figure 3** – Energy content of wet distillers grains plus solubles when replacing corn at different inclusions.



used (average of 40%), the energy was 130% that of corn. Vander Pol et al., (2005b) conducted an economic comparison for cattle fed no WDGS, and 10, 20, 30, 40, and 50% WDGS. In this study, corn was evaluated using 10-year average price, and with either a $0.05 or $0.10 increase in price per bushel, due to basis on corn near an ethanol plant. Scenarios were compared for feedlots near the plant, 30, 60, and 100 miles from the plant. Costs that were accounted for were extra feeding cost due to handling diets greater in moisture, bushel price, and distance from the plant. Increased return was based on energy value of WDGS (Figure 4) at each level fed. The optimum level for feedlot producers is 30 to 40% of diet DM when plants are within 30 miles of the ethanol plant. As the distance increases from the plant to the feedlot, the optimum inclusion of WDGS decreases to 20 to 30%. This comparison suggests that more WDGS can be fed than traditional levels of 15 to 20%; however, the optimum inclusion is dependent on more than just the energy value of WDGS. Factors such as price, cattle performance, distance from the plant, and corn price influence the economic optimum inclusion amount. Of course, these economic returns are dependent on our assumptions of purchasing WDGS at 95% of corn price.

## COMPOSITION

Table 2 contains data on plant averages and some indication of variation for various corn milling co-products. Variation exists from plant to plant and within a plant. These table values should not replace sampling and analysis of feed from individual plants. The dry distillers grains plus solubles (DDGS), WDGS, and condensed corn distillers solubles (CCDS) are all from one plant in Nebraska and represent average values for 2003. The standard deviations are for composite weekly samples, not for load variation. Sampling frequency is important as actual variation observed from load to load at a feedlot is quite different than variation from weekly samples. The plant with an excellent database on variability is the Cargill Blair facility. The standard deviation is low on DM change from load to load. This relates to two things: process development to minimize variation and culture of those operating the plant to minimize variation in feed products. The coefficient of variation (CV, %) can be calculated as: (standard deviation/average) x 100. The energy values used in Table 2 are based on performance data summarized in this paper and other reviews. In another recent review of composition and variation in plants and across plants, the reader is referred to Holt and

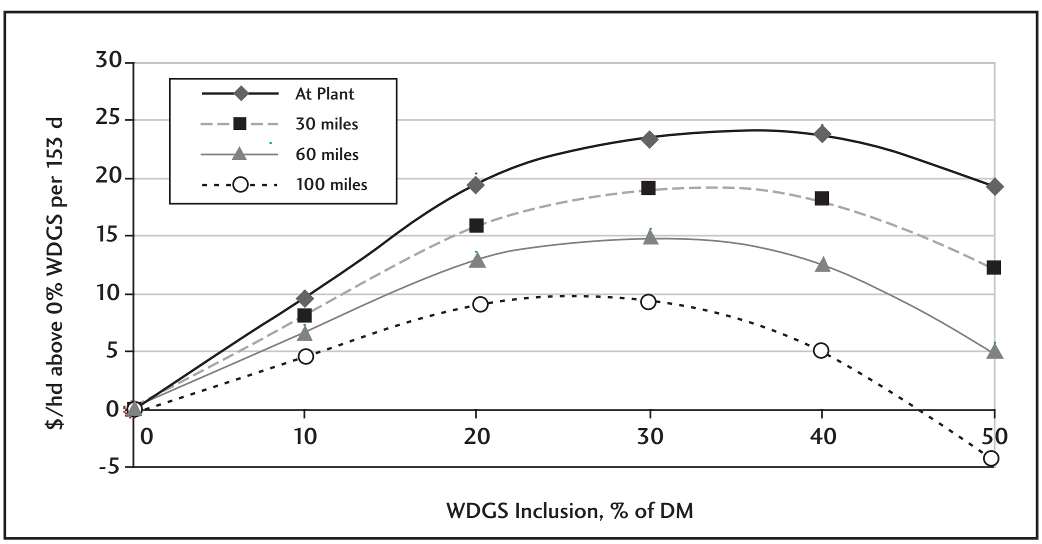



**Figure 4** – Economic return from feeding WDGS when fed at 0, 10, 20, 30, 40, or 50% of diet DM.

**Table 2.** Nutrient composition of selected corn milling co-products.

| Feedstuff:[a] | DRC[b] | WCGF-A | WCGF-B | DDGS[c] | WDGS[c] | CCDS[c] | MWDGS | steep[d] |
|---|---|---|---|---|---|---|---|---|
| DM | 90.0 | 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 |
| UIP, % of CP | 60.0 | 20.0 | 20.0 | 65.0 | 65.0 | 65.0 | NA | 20.0 |
| 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, % | 90.0 | 90.0 | 94.5 | 101 | 112 | 112 | NA | 113 |
| NEg, Mcal/lb | 0.70 | 0.71 | 0.80 | 0.78 | 0.87 | 0.87 | NA | 0.88 |

[a] DRC=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.

[b] DRC values based on NRC (1996) values with approximately 3500 samples

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

[d] DM values represent variation from daily composites for a 60-d period. Other nutrients are based on monthly composites for 2002 and half of 2003.

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

Pritchard (2004). Moisture and DM variation are probably of greatest importance with wet co-products. However, both fat and S can vary in wet distillers grains which could lead to changes in energy value and potential for toxicity, respectively.

## USE IN FORAGE DIETS

Beef calves from weaning until they enter feedlots, developing heifers and beef cows are fed primarily forage diets. Especially in the winter, forages are low in protein and phosphorus and need to be supplemented. Corn gluten feed contains highly digestible fiber and degradable protein which are good sources of energy and protein for rumen microbes, especially in forage-based diets (DeHaan et al., 1983). Wet and dry corn gluten feed were compared to dry-rolled corn for growing calves fed grass hay, wheat straw, and corn stalklage. The gluten feed or corn replaced 40% of the forage (Oliveros et al., 1987). The supplements nearly doubled gains and improved feed conversion (Table 3). Wet and dry gluten feeds had better feed conversions than corn and WCGF had better feed conversion than DCGF. The apparent energy value of DCGF was 10% greater than corn, while WCGF was 31% higher than DCGF and 42% greater than corn in these forage-based diets.

**Table 3.** Wet or dry corn gluten feed or corn in forage based diets for growing calves[a].

| | Forage | Corn | DCGF | WCGF |
|---|---|---|---|---|
| DMI, lb/d | 11.7 | 18.0 | 16.4 | 16.2 |
| ADG, lb | 1.16 | 2.25 | 2.15 | 2.36 |
| Feed/gain | 10.5 | 8.01 | 7.64 | 6.86 |

[a]Balanced for 11.5% CP.

**Table 4.** Escape Protein Values

| Source | % protein escape |
|---|---|
| Soybean meal | 30 |
| Wet distillers grains | 60-70 |
| Dried distillers grains | 60-70 |
| Distillers solubles | 30 |

**Table 5.** Wet and Dry Grains for Calves

| Supplement | ADG | Protein efficency[a] | ADIN[b] |
|---|---|---|---|
| Urea | 1.00 | -- | --- |
| WG | 1.46 | 2.6 | --- |
| DDGS | 1.42 | 2.0 | 9.7 |
| DDGS | 1.47 | 1.8 | 17.5 |
| DDGS | 1.54 | 2.5 | 28.8 |

[a]Pounds gain/lb supplemental protein.
[b]Acid detergent insoluble nitrogen, measure of amount of heating.

Clearly, gluten feed is an excellent source of nutrients for forage-based diets. There is little to no starch in gluten feed, which results in no negative effect on fiber digestion. The DIP in gluten feed is an excellent source of protein for microbes. Protein in forages is highly degraded in the rumen. In certain production situations, cattle may need to be supplemented with undegraded (UIP; bypass) protein to meet metabolizable protein (MP) requirements. Distillers grains (wet or dry) are an excellent source of undegraded protein and phosphorus. The values obtained from feeding trials for undegraded protein are shown in Table 4. Wet grains were compared to dry grains and the value of the protein was similar (Table 5). This suggests that the high escape protein value of distillers grains is due to the innate characteristics of the protein and not to drying or moisture content, and does not appear to be influenced by acid-detergent insoluble protein (ADIN) which is a common measure of heat damaged protein.

The value of distillers grains as a protein supplement is illustrated in Table 6. We have shown the formulation and cost of a soybean meal based supplement and a distillers grains based supplement. They should have equal feeding value but the distillers grains supplement is less expensive because of the high escape value of the protein. Less expensive midds and urea can then be used in the supplement. This illustrates just how economical distillers grains can be as a supplement to stockers, heifers and cows.

Stocker calves, developing heifers and cows may need energy supplementation in addition to supplemental protein and phosphorus. It is advantageous if the same commodity can be used for supplemental energy as well as protein. We previously stated that distillers grains should have 120% the energy value of corn grain. Additional advantages for distillers grains are that it contains very little starch and therefore should not depress fiber digestion.

During drought conditions, these co-products may be very competitive as energy supplements for use by ranchers. When forage quality is poor (winter) or quantity is limiting (drought), co-products may fit. Research efforts at the University of Nebraska-Lincoln have focused on the usefulness and value of dry co-products in cow-calf situations.

**Table 6.** Value of Distillers Grains - 40% Supplement

| | SBM | DDGS |
|---|---|---|
| SBM | 78.7% | --- |
| DG | - | 60% |
| Midds | 20.3 | 32.8 |
| Urea | --- | 6.2 |
| Minerals | 1.0 | 1.0 |
| Ingredient cost | $153 | $95 |

Prices: SBM, $161; DDGS, $95; Midds, $61; Urea, $280 (corn $75).

Loy et al., (2004) concluded that DCGF 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 their study, a treatment system (TRT) was compared to their conventional management using over 550 heifers in each group across two years. The TRT system utilized only grazed winter forage and DCGF supplementation compared to some winter grazing, with hay and protein supplementation. Performance differences are presented in Table 7; however, little differences were observed in developing heifer performance by design. The major implication was reduced costs ($6.71 per heifer) through the winter while maintaining excellent performance and reproduction.

A similar experiment was conducted using DDGS (Stalker et al., 2006). Because of the higher energy content of DDGS, a smaller amount was needed to meet protein and energy requirements of these bred heifers (1353 heifers were used). Feeding DDGS and grazing winter range with heifers led to slightly better winter gains and changes in body condition compared to the hay-fed, control heifers. Pregnancy rates were 97% for both treatments. Most important, $10.47 per heifer was saved in feed costs by using DDGS and winter range versus a conventional system of hay, supplement, and range.

**Table 7.** Weight, body condition, and conception rates of heifers in two systems.

| Item | CON | TRT |
|---|---|---|
| **Year One** | | |
| 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 |
| **Year Two** | | |
| 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, %e | 96.1 | 96.4 |

[a,b] Unlike superscripts within a row differ, P < 0.05.
[c,d] Unlike superscripts within a row differ, P < 0.10.
[e] Percentage pregnant with second calf. P-value reflects chi square analysis.

**Table 8.** Growing calf performance over 84 days when fed native grass hay (CP = 8.7%) supplemented with either corn or DDG for two levels of gain. Net energy was 27% greater for DDG compared to corn (Loy et al., 2003a).

| | | Low[a] | High[a] |
|---|---|---|---|
| ADG, lb/d | Corn | .81 ± .06 | 1.57 ± .05 |
| | DDGS | .99 ± .05 | 1.89 ± .05 |
| Feed conversion | Corn | 15.9 ± .5 | 9.8 ± .5 |
| (DMI/ADG) | DDGS | 12.8 ± .5 | 8.0 ± .5 |

[a]LOW = supplement fed at 0.21% BW, HIGH = supplement fed at 0.81% BW.
[b]DDGS = dry distillers grains; DRC = dry rolled corn

An experiment was conducted with 120 crossbred heifers to determine the value of dry distillers grains (DDGS) in high-forage diets, and to evaluate the effect of supplementing daily compared to three times weekly (Loy et al., 2003). Heifers were fed to consume grass hay ad libitum and supplemented with DDGS or dry rolled corn (DRC). 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 per day), but were not more efficient than those supplemented on alternate days (Table 8). At both levels of gain, DDGS heifers gained more and were more efficient than DRC fed heifers. The calculated net energy values for DDGS were 27% greater than for DRC.

Ten ruminally-cannulated heifers received no supplement, dry distillers grains (DDGS) daily, DDGS on alternating days, dry rolled corn daily, or corn on alternating days (Loy et al., 2004). Hay intake was higher for non-supplemented than for supplemented heifers (Table 9). No intake differences were observed between DDGS and

**Table 9.** Treatment effects on intake, neutral detergent fiber disappearance, ruminal pH, and intake pattern.

| Item | CON[a] | DRC-D[a] | DRC-A[a] | DDGS-D[a] | DDGS-A[a] |
|---|---|---|---|---|---|
| Hay DMI, %BW[b, c] | 1.88 | 1.69 | 1.58 | 1.69 | 1.66 |
| Total DM, %BW[b, c] | 1.88 | 2.10 | 1.98 | 2.09 | 2.06 |
| NDF disappearance, %/hour[b,d] | 4.34 | 3.43 | 3.65 | 4.09 | 4.01 |
| Average ruminal pH[b,d] | 6.30 | 6.22 | 6.22 | 6.12 | 6.19 |
| Meals per day[c,e] | 5.9 | 6.6 | 4.0 | 6.0 | 5.1 |

[a] CON = no supplement; DRC-D = dry rolled corn supplement fed at 0.46% of BW daily; DRC-A = DRC at 0.92% of BW on alternate days; DDGS-D = dry distillers grains + solubles supplement fed at 0.45% of BW daily; DDGS-A = DDGS at 0.90% of BW on alternate days.
[b] CON vs supplemented treatments, P < 0.05
[c] Supplementation frequency effect, P < 0.10
[d] DDGS vs DRC, P < 0.05
[e] Supplement x frequency interaction, P < 0.08

corn-supplemented heifers. Heifers supplemented daily had higher and more consistent intakes than those in alternate-day treatments, particularly within corn-supplemented heifers. Ruminal pH and hay fiber disappearance were greater in non-supplemented heifers. Corn-supplemented heifers had slower rates of fiber disappearance than DDGS-supplemented.

Dry distillers grains contain approximately 65% UIP (% of CP), consequently forage based diets that include dried distillers grains fed as an energy source are commonly deficient in degradable intake 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 urea that is recycled when DDGS is included in a forage based diet is not known. The objective of these trials was to determine if added DIP (i.e. urea) is required in forage based diets where DDGS is included at levels in excess of the MP requirement.

Two experiments evaluated supplemental degradable intake protein requirements when dried 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 degradable intake protein but with excess in metabolizable protein. In both experiments, no response in performance was observed when urea was added to the diet (Table 10). Sufficient urea was probably recycled to correct the degradable intake protein deficiency. These studies indicate adding urea to meet the degradable intake protein requirement is not necessary when dried distillers grains are fed as an energy source in forage based diets. In a similarly designed experiment with DDGS fed to finishing cattle at either 10 or 20% of diet DM, no advantage was observed between cattle supplemented with urea (DIP) or not suggesting recycling was occurring in finishing diets supplemented with 10 or 20% DDGS (Vander Pol et al., 2005c). However, some numerical differences suggested a conservative approach would be to follow NRC (1996) guidelines for DIP supplementation if distillers grains are provided at less than 20% of diet DM.

Thirty heifers grazing smooth bromegrass were individually supplemented with 0, 1.0, 2.1, 3.1, or 4.2 lb per head per day (DM) dried distillers grains (DDGS) for 84 days to determine effects of DDGS supplementation on ADG and forage intake, and to determine the value of DDGS in grazing enterprises (MacDonald et al, 2004). Forage intake was estimated using the 1996 NRC model.

Supplementation of DDGS resulted in a linear increase in ADG (Figure 5) and decreased estimated forage intake (Figure 6). Morris et al. (2005) fed either a high quality

**Table 10.** Performance and allantoin to creatinine ratios in urine of animals fed diets where 0, 33, 67, 100, or 133% of the NRC predicted degradable intake protein requirement was met with supplemental urea

| | Diet | | | | | F-Test | |
|---|---|---|---|---|---|---|---|
| Item | 0 | 33 | 67 | 100 | 133 | SEM | P-value |
| Experiment 1 | | | | | | | |
| Initial BW, lb | 611 | 611 | 615 | 617 | 614 | 11 | 0.99 |
| Final BW, lb | 694 | 697 | 680 | 702 | 702 | 15 | 0.85 |
| ADG, lb | 1.06 | 1.03 | 0.93 | 1.01 | 1.04 | 0.07 | 0.77 |
| Total DMI, lb | 11.3 | 11.4 | 11.4 | 11.5 | 11.4 | 0.2 | 0.95 |
| F:G | 11.1 | 11.8 | 13.2 | 11.8 | 11.7 | 0.9 | 0.54 |
| Allantoin:creatinine | 0.66 | 0.66 | 0.56 | 0.68 | 0.67 | 0.08 | 0.84 |
| Experiment 2 | | | | | | | |
| Initial wt., lb | 452 | 449 | 1 | 0.10 | | | |
| Final wt., lb | 579 | 585 | 4 | 0.38 | | | |
| ADG, lb | 1.53 | 1.63 | 0.05 | 0.17 | | | |
| Total DMI, lb | 11.9 | 11.6 | 0.5 | 0.76 | | | |
| F:G | 9.8 | 9.1 | 0.5 | 0.33 | | | |
| Allantoin:creatinine | 0.89 | 0.89 | 0.04 | 0.98 | | | |

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

or low quality forage diet to individually fed heifers and supplemented either 0, 1.5, 3.0, 4.5, or 6.0 lb of DDGS per day. When DDGS was supplemented, forage intake was decreased and ADG was increased. DDGS may be an attractive forage supplement due to increased revenue from additional ADG and savings from decreased forage intake.

The last area where co-products may fit in forage situations is with grazing corn residues. Incremental levels of WCGF were fed to calves grazing corn residues. Based on statistical and economical analysis of the data collected, feeding wet corn gluten feed (5.0-6.5 lb/ head/day; DM basis) will increase stocking rate on corn residue and reduce winter costs by 11%. Given that 3.5 lb DM/day wet corn gluten feed will meet the protein and phosphorus needs of calves, and feeding above 6.0 lb/d will not increase gains, wet corn gluten feed should be fed at 3.5-6.0 lb DM/day, producing gains from 1.28-1.88 lb/day (Jordon et al., 2001). In a similarly designed study using DDGS, Gustad et al. (2006) fed 1.5, 2.5, 3.5, 4.5, 5.5, and 6.5 lb/steer/d to calves grazing corn residue. Gains increased quadratically (P < 0.01) with ADG ranging from 0.90 to 1.81 lb.

## CORN PROCESSING

Feeding corn milling co-products in feedlot diets reduces acidosis-related challenges due to starch. Both WCGF and

**Figure 5.** Effect of supplemental dried distillers grains on ADG.

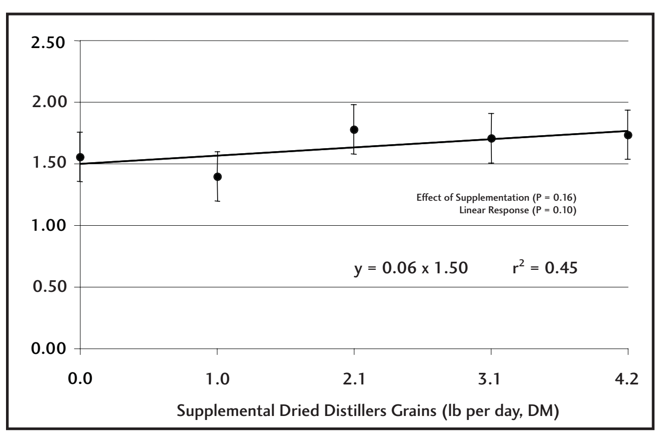
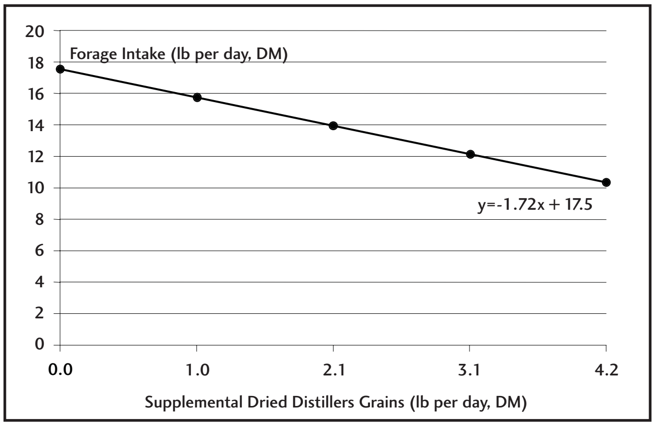


**Figure 6.** Effect of supplemental dried distillers grains on forage intake as predicted by the 1996 NRC model.




WDGS have little to no starch remaining following the milling process. Therefore, feeding these co-products will dilute the starch that is fed and may influence rumen metabolism. Krehbiel et al., (1995) observed a decrease in subacute acidosis when WCGF was fed to metabolism steers. In many experiments, feeding WCGF results in increased DMI, which would be considered a symptom often observed with subacute acidosis.

Because processing corn increases rate of digestion by microbes, rumen acid production is increased and the risk of acidosis is increased (Stock and Britton, 1993). Feeding wet corn gluten feed (WCGF) helps prevent the risk of acidosis with high-grain diets (Krehbiel et al., 1995). Numerous studies have been conducted at the University of Nebraska-Lincoln to determine if energy values are markedly improved in diets containing WCGF when corn is more intensely processed. Scott et al. (2003) evaluated various corn processing techniques (Table 11). Feed conversions were improved as processing intensity increased when feeding calves or yearlings. Ranking of processing based on feed conversions (lowest to highest) was whole, dry-rolled (DRC), finely ground (FGC), high-moisture (HMC), and steam-flaked (SFC) for

**Table 11** – Effect of corn processing when fed with wet corn gluten feed (Macken et al., 2006; Scott et al., 2003).

| **25% WCGF** (Macken et al., 2006) | Processing method[a] | | | | |
|---|---|---|---|---|---|
| | **DRC** | **FGC** | **RHMC** | **GHMC** | **SFC** |
| ADG, lb | 4.23 | 4.35 | 4.21 | 4.24 | 4.33 |
| Feed:gain ratio, DM | 5.49[b] | 5.29[c] | 5.13[d] | 5.05[d] | 4.91[e] |
| NEg (corn), Mcal/cwt | 70.0 | 73.4 | 76.4 | 77.7 | 80.4 |
| Fecal starch, % | 19.2[b] | 11.8[c] | 10.6[cd] | 8.4[d] | 4.1[e] |

| **32% WCGF with calves** (Scott et al., 2003) | Processing method[a] | | | | |
|---|---|---|---|---|---|
| | **Whole** | **DRC** | **FGC** | **RHMC** | **SFC** |
| ADG, lb | 4.18 | 4.24 | 4.17 | 4.15 | 4.25 |
| Feed:gain ratio, DM | 5.92[b] | 5.52[c] | 5.32[d] | 5.26[de] | 5.18[e] |

| **22% WCGF with yearlings** (Scott et al., 2003) | Processing method[a] | | | | |
|---|---|---|---|---|---|
| | | **DRC** | **FRC** | **RHMC** | **SFC** |
| ADG, lb | | 3.98[b] | 3.95[b] | 4.02[b] | 4.22[c] |
| Feed:gain ratio, DM | | 6.09[bc] | 6.15[b] | 5.97[c] | 5.54[d] |

[a] DRC = dry rolled corn, FGC = fine ground corn, FRC = fine rolled corn, RHMC = rolled high moisture corn, GHMC = ground high moisture corn, SFC = steam flaked corn, whole = whole corn.
[b,c,d,e] Means with different superscripts differ ($P < 0.05$).

**Table 12.** Effect of corn processing when fed with wet distillers grains (Vander Pol et al., 2006).

**30% WDGS included in all diets**

| | Processing method[e] | | | | | |
|---|---|---|---|---|---|---|
| | Whole | DRC | DR/HM | HMC | SFC | FGC |
| DMI, lb/ | 23.1[a] | 22.6[a] | 21.5[b] | 21.0[bc] | 20.4[c] | 20.4[c] |
| ADG | 3.85[a] | 4.05[b] | 3.91[ab] | 3.89[ab] | 3.59[c] | 3.38[d] |
| F:G | 6.07[a] | 5.68[bc] | 5.61[bc] | 5.46[c] | 5.76[b] | 6.15[a] |

[a,b,c,d] Means with different superscripts differ ($P < 0.05$).
[e] DRC = dry rolled corn, FGC = fine ground corn, HMC = high moisture corn, SFC = steam flaked corn, whole = whole corn.

calves. Relative improvements in F:G for DRC, FGC, HMC and SFC compared to whole corn were 6.8%, 10.1%, 11.1% and 12.5%, respectively. When fed to yearlings, whole corn was not included, but response to processing was not as favorable as with calves. Feeding fine rolled corn (FRC) and HMC did not significantly improve feed conversion compared to DRC. Macken et al. (2006) fed DRC, FGC, SFC, and HMC processed as rolled (roller mill) and ground (tub grinder) to calves with all diets containing 25% WCGF. Whole corn was not fed in this study, but processing corn more intensely significantly improved performance. Net energy calculated from performance (Owens et al., 2002 and NRC, 1996) was increased by 4.8%, 9.1%, 11.0% and 14.9% for FGC, RHMC, GHMC and SFC, respectively, compared to DRC.

Apparently, HMC appears to have greater energy value when diets contain WCGF than what was previously observed (diets not containing WCGF). Because HMC has greater ruminal starch digestibility than DRC or SFC (Cooper et al., 2002), HMC when fed to cattle has a greater potential for acidosis (when fed alone). However, feeding HMC in combination with WCGF appears to increase efficiency of utilization of HMC, perhaps by reducing acidosis. For example, the energy value of HMC in diets comprised of HMC as the only grain source is lower than that observed when fed in combination with other grains (Stock et al., 1991) or in co-product diets. Previous reviews reported that HMC feeding resulted in 2% greater efficiency than DRC (Owens et al., 1997). However, based on work with HMC-based diets containing 20 to 35% WCGF, cattle are 5 to 10% more efficient than those fed WCGF and DRC. Our conclusion is that intense processing has tremendous value in diets containing WCGF.

However, it was unclear what the effect of corn processing is in diets containing WDGS. Vander Pol et al., (2006) fed diets containing either whole, DRC, HMC, a 50:50 blend of HMC and DRC (DM basis), SFC, or FGC to calf-feds for 168 days. Cattle fed DRC, HMC, or a combination of HMC and DRC gained more and were more efficient (lower feed conversion) than cattle fed whole corn (Table 12). Interestingly, cattle fed steam-flaked corn and finely ground corn were not as efficient. It is unclear why finely ground and steam flaked corn did not respond when diets contained WDGS similar to diets containing WCGF. However, the diets containing HMC and WDGS resulted in excellent performance. More work is in progress to address the optimum corn processing method with diets containing WDGS.

## ROUGHAGES

Roughages are often included at low levels (<12% of diet DM) to control acidosis and maintain intake in feedlot cattle (Stock and Britton, 1993). Since co-products reduce the occurrence of acidosis in feedlot cattle, then perhaps roughage levels may be reduced from conventional levels in diets containing co-products. Farran et al., (2004) fed either 0 or 35% WCGF with either 0, 3.75, or 7.5% alfalfa hay at each level (i.e., treatments were factorialized with WCGF level and hay level). Table 13 provides performance of cattle fed each diet. There was a significant interaction between WCGF and alfalfa level for feed conversion, therefore, only simple effects are presented in Table 13. With 0% WCGF, increasing alfalfa level increased ADG and DMI with no effect on feed conversion. With 35% WCGF, increasing alfalfa hay increased ADG and DMI, but hindered (increased) feed conversion linearly. It appears that roughage can be decreased (eliminated) in DRC-based diets that contain 35% or more WCGF. However, ADG was reduced for the 0% hay, 35% WCGF treatment which has economic implications. Similar results have been observed with SFC-based diets where alfalfa can be reduced to 2% with at least 25% WCGF (Sindt et al., 2001). Parsons et al., (2001) observed no change in feed conversion when roughage was decreased from 9 to 0% alfalfa in SFC diets with 40% Sweet Bran WCGF. However, in their study, DMI and ADG decreased linearly. Just as with data in conventional, corn-based diets, optimum amount of roughage appears to be dependent on grain processing and level of WCGF. No data are available addressing roughage level in diets with distillers grains alone, but we are currently working on it.

## COMBINATIONS OF CO-PRODUCTS

With the large expansion of ethanol plants in the Midwest, an option for many feedlots will be utilizing both WDGS and WCGF at the same time. In addition to their commercial availability, another reason for feeding a combination of WDGS and WCGF is due to their nutritional profiles. Synergistic effects in feeding a combination of these co-products may be observed because of differences in fat, effective fiber, and protein components. Loza et al., (2004) fed yearling steers a 50:50 blend of WDGS and WCGF (DM basis) at inclusion levels ranging from 0 to 75% DM. This experiment also evaluated different forage levels. A level of 7.5% alfalfa hay was used across all the treatments. Additional treatments were also evaluated using a lower alfalfa level with each of the co-product diets, decreasing the forage inclusion as the rate of inclusion of co-products in the diets increased (i.e. 25% blend had 5% alfalfa in the lower forage treatment, 75% blend had 0% alfalfa in the lower forage treatment). Results indicated that there were no differences in cattle performance between forage levels for each co-product blend level. The lack of differences in performance with decreasing forage would indicate that the byproduct inclusion was enough to prevent the negative consequences of sub-acute acidosis (Table 14). The analysis of the pooled data from each co-product level indicated that the performance of the steers fed the maximum co-product level (75%), regardless of the forage level, was not different than a typical corn based diet (0% co-product blend). However, the diets including a 25 and 50% blend of WDGS and WCGF resulted in significantly better animal performances than the control. In conclusion, it is feasible to decrease the forage levels with high inclusion of co-products. Producers may also feed levels as high as 75% without negatively affecting

**Table 13.** Effect of increasing alfalfa hay level in diets with and without WCGF for finishing yearlings fed dry-rolled corn based diets.

| | 0 % WCGF | | | 35% WCGF | | |
|---|---|---|---|---|---|---|
| Alfalfa level | 0 | 3.75 | 7.5 | 0 | 3.75 | 7.5 |
| DMI[a] | 22.7 | 23.8 | 24.2 | 23.3 | 24.9 | 25.6 |
| ADG[a] | 3.68 | 4.01 | 4.01 | 3.94 | 4.07 | 4.07 |
| Feed to Gain[b] | 6.21 | 5.95 | 6.02 | 5.95 | 6.10 | 6.25 |

[a] Non-significant interaction between WCGF and alfalfa level; Significant ($P < 0.10$) increase due to WCGF; Significant ($P < 0.03$) linear increase for alfalfa level.

[b] WCGF x alfalfa level interaction ($P < 0.09$); Linear effect ($P < 0.06$) of alfalfa level within 35% WCGF, no effect of alfalfa hay with 0% WCGF.

**Table 14**. Effect of different inclusion levels of a 50:50 blend of WCGF and WDGS (DM basis) and forage levels fed to yearling steers.

| Blend: | 0%DM | 25% DM | | 50% DM | | 75% DM | |
|---|---|---|---|---|---|---|---|
| Alfalfa: | 7.5 | 5 | 7.5 | 2.5 | 7.5 | 0 | 7.5 |
| DMI, lb/day | 24.3[a] | 26.3[bc] | 26.5[b] | 25.4[c] | 26.1[bc] | 23.0[d] | 23.6[ad] |
| ADG, lb/day | 3.99[a] | 4.70[b] | 4.57[b] | 4.55[b] | 4.56[b] | 3.86[a] | 3.93[a] |
| F/G | 6.10[a] | 5.60[c] | 5.80[bc] | 5.59[c] | 5.73[bc] | 5.97[ab] | 6.01[ab] |

[a,b,c,d]Means with different superscripts differ ($P<0.05$).
All diets contain a 50:50 DRC- HMC blend and 5% supplement.

performance. However, optimum inclusion rates of a co-product blend would be between 25 and 50% DM.

Feeding a combination of WDGS and WCGF also offers producers greater flexibility. A major challenge facing some ethanol plants is not having feed for cattle feeders on a consistent basis. Cattle do not respond well if either WDGS or WCGF, as sole co-products in the diet, are removed and replaced with corn abruptly. Therfore, one approach would be to feed a combination to ensure that at least one co-product is consistently in the ration.

## NEW ETHANOL INDUSTRY CO-PRODUCTS

The evolving ethanol industry is continually striving to maximize ethanol production efficiency. Changes associated with this progress will provide innovative new co-product feeds for producers to utilize that may be quite different nutritionally when fed to cattle. One example of a new co-product feed is Dakota Bran Cake. Bran cake is a distillers co-product feed produced as primarily corn bran plus distillers solubles produced from a hybrid wet and dry milling process. On a DM basis, bran cake contains less protein than WDGS and WCGF, similar NDF to both feeds and similar to slightly less fat content as WDGS. A study by Bremer et al., (2005) evaluated Dakota Bran Cake inclusion up to 45% DM by comparing 0, 15, 30, and 45% of diet DM. Results indicated improved final weight, ADG, DMI and F:G compared to feeding a blend of high-moisture and dry-rolled corn, suggesting this specific feed has 100 – 108% of the energy value of corn. Dakota Bran Cake is only one example of how new ethanol industry co-products will feed relative to traditional finishing rations. Each new co-product feed needs to be analyzed individually for correct feeding value. Changes to plant production goals and production efficiency have a significant impact on the feeding value of co-products produced.

## CONCLUSIONS

Distillers grains have 120 to 150% the energy value of dry rolled corn in beef finishing diets. Acidosis control is likely responsible for the higher apparent values and may be the primary advantage of using distillers grains. Drying appears to reduce the energy value. Dry grains have 120 to 127% the energy value of dry rolled corn in high-forage diets. The high undegraded value of the protein makes it an excellent protein source for young, growing cattle and lactating cows. Alternate day (or three days/week) feeding appears to be feasible and distillers grains may have an advantage to grains, NPN sources and more degradable protein sources in alternative day feeding systems.

With feedlot cattle, more intense corn processing may be optimal for diets containing WCGF. It appears that with diets containing WDGS, high-moisture corn and dry-rolled corn work well. Roughages may be minimized in finishing diets containing co-products. In the future, with increased supply of co-products, feeding combinations of WDGS and WCGF may be advantageous. It also appears that many new co-products will be available in the future as the processes of making ethanol and other products from corn evolve. These "new" feeds should be evaluated with performance data to determine how the new co-products will feed.

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