FEEDING OF WET CORN MILLING BYPRODUCTS TO BEEF CATTLE

G.E. Erickson, T.J. Klopfenstein, K. Vander Pol, V. Bremer, and P. Loza
Department of Animal Science
University of Nebraska, Lincoln, NE

INTRODUCTION

Corn milling byproducts 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; however, an increase in supply of both WDGS and WCGF is 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 value and implications, and economics of using WDGS. Some other management issues will be discussed as well including grain processing when these byproducts are used in feedlot diets, roughage level when these byproducts are used, and feeding combinations of WDGS and WCGF. Forage fed situations will not be covered primarily because wet byproducts are not common ingredients in many forage feeding situations. However, wet byproducts work well in forage based diets performing similar to or better than dry byproducts.

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). 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 2 main categories, depending on the ratio of steep to bran. Because of differences in the amount of steep added, WCGF has approximately 100 to 108% 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 increases in steep added in WCGF.

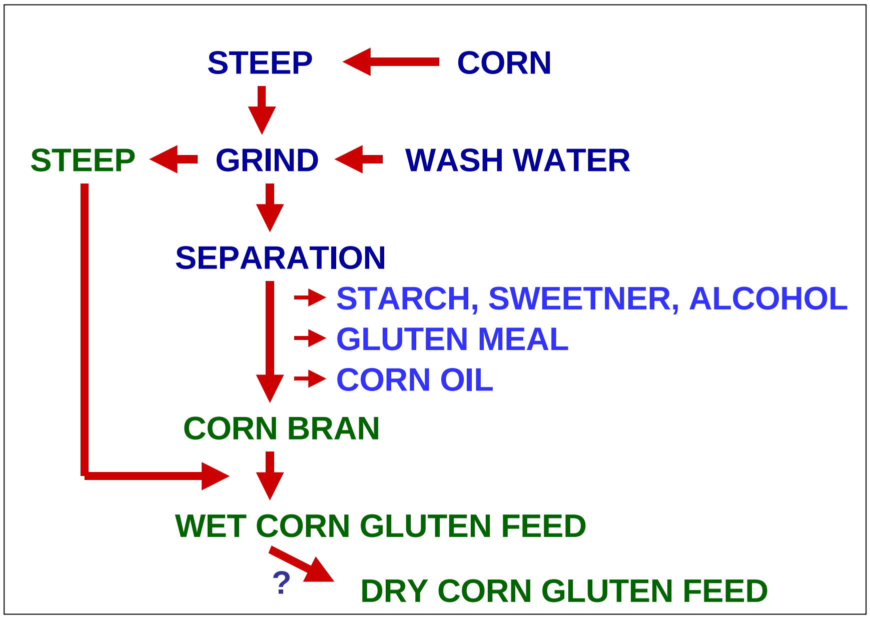

Figure 1. Schematic of the wet milling industry resulting in wet or dry corn gluten feed.

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 WDG (wet distillers grains) or DDG (dry distillers grains). Our assumption is that the distillers grains will contain some solubles. The milling process (Figure 2) is relatively simple where corn (or other starch sources) 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. As a result, all the nutrients are concentrated 3-fold because most grains contain approximately 2/3 starch. For example, if corn is 4% oil, the WDG or DDG 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. Experiments evaluating the use of wet distillers byproducts 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 byproduct consistently improved feed efficiency. Figure 1 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 byproduct. 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 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 3) 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; 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.

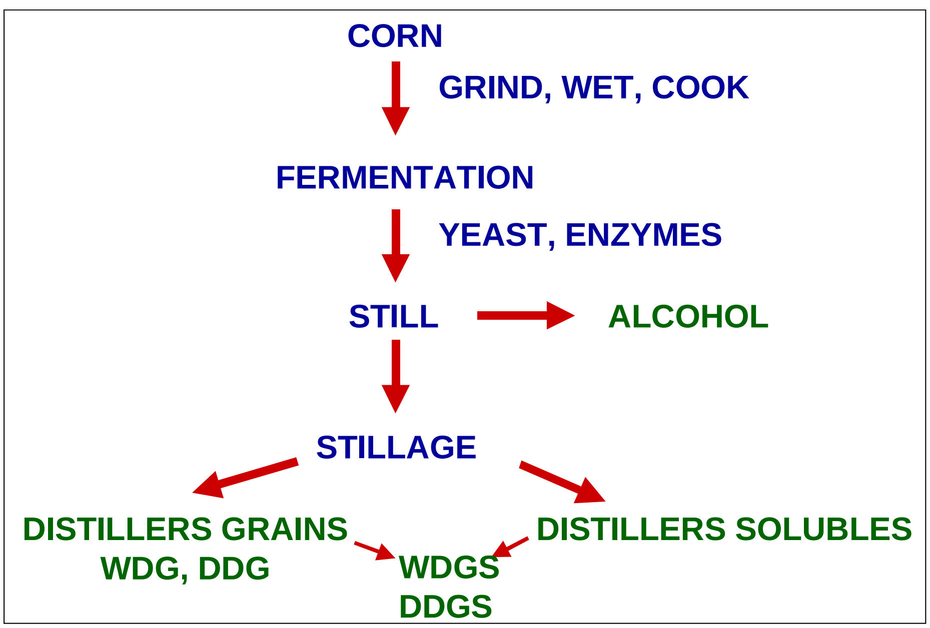

Figure 2. Schematic of the dry milling industry with the feed products produced.

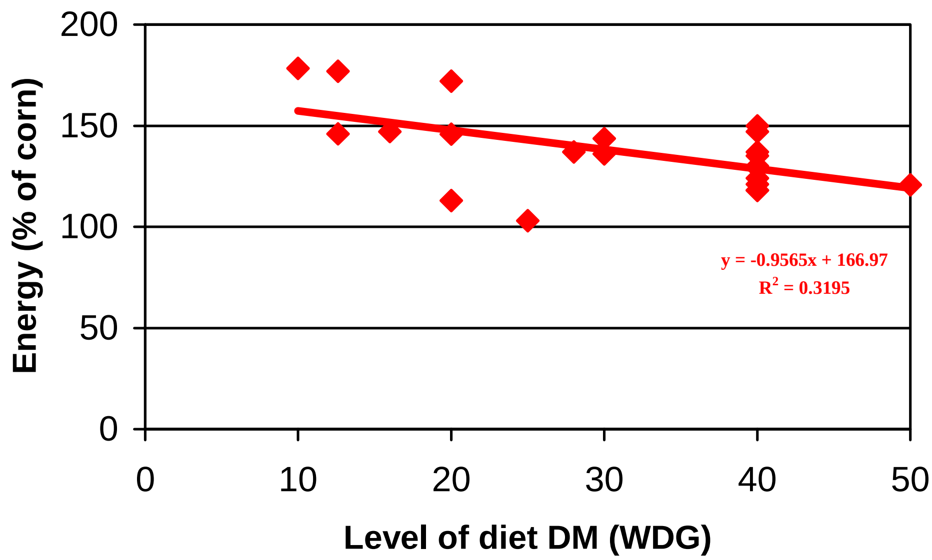

Figure 3. Energy content of wet distillers grains plus solubles when replacing corn at different inclusions.

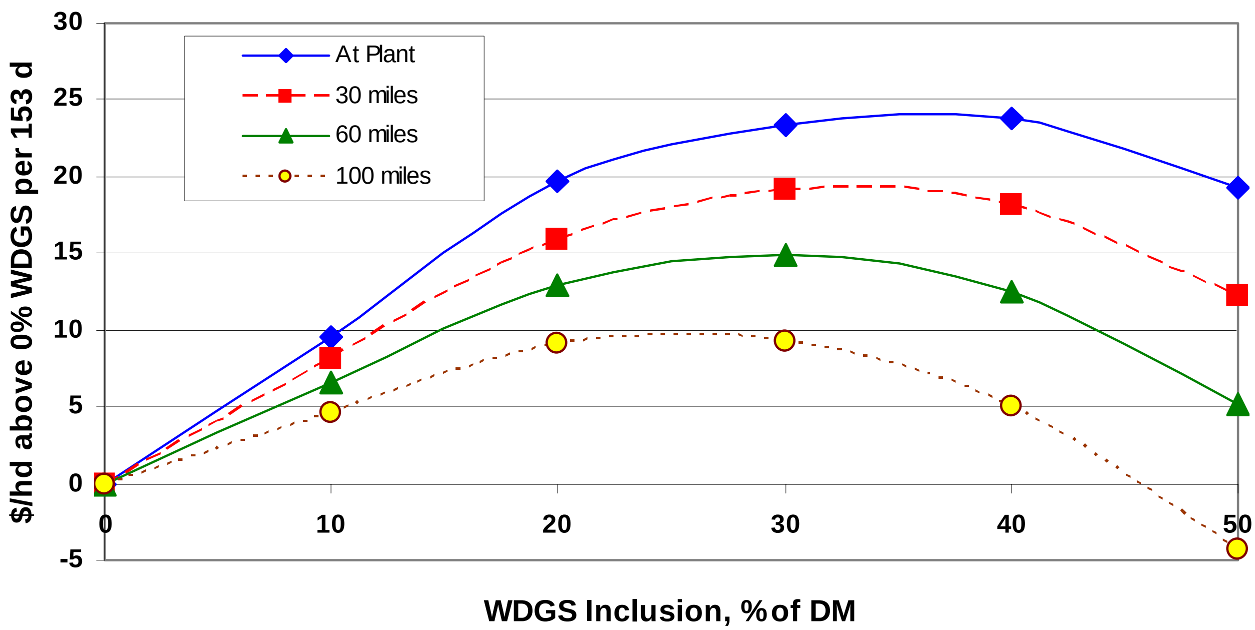

Figure 4. Economic return from feeding WDGS when fed at 0, 10, 20, 30, 40, or 50% of diet DM.

COMPOSITION

Table 1 contains data on plant averages and some indication of variation for various corn milling byproducts. 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. 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 plants 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 3 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 Pritchard (2004). Moisture and DM variation are probably of greatest importance with wet byproducts. However, both fat and S can vary in wet distillers grains which could lead to changes in energy value and potential for toxicity, respectively.

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
UIP, % 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, %	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

[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.

CORN PROCESSING

Feeding corn milling byproducts in feedlot diets reduces acidosis-related challenges from starch fed to ruminants. Both WCGF and WDGS have little to no starch remaining following the milling process. Therefore, feeding these byproducts 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 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 2). 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 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 byproduct 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. Interestingly, cattle fed steam-flaked corn and finely ground corn were not as efficient. It is unclear why more intense processing did not respond when diets contained WDGS similar to diets containing WCGF. More work is needed in this area.

Table 2. 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 3. 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.

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 byproducts reduce the occurrence of acidosis in feedlot cattle, then perhaps roughage levels may be reduced from conventional levels in diets containing byproducts. 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 4 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 4. 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. 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. It also appears that conversions are relatively constant, but cattle may consume less feed and gain less at low levels of WCGF inclusion. No data are available addressing roughage level in diets with distillers grains alone.

Table 4. 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.

COMBINATIONS OF BYPRODUCTS

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 reasons for feeding a combination of WDGS and WCGF is due to their nutritional profiles. Synergistic effects in feeding a combination of these byproducts may be observed because of differences in fat, effective fiber, and protein components. Loza et al., (2004) fed yearling steers a combination of 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, and a lower alfalfa level was included in each of the byproduct diets, decreasing the forage inclusion as the rate of inclusion of byproducts 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 byproduct 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 5). The analysis of the pooled data from each byproduct level indicated that the performance of the steers fed the maximum byproduct level (75%), regardless of the forage level, was not different than a typical corn based diet (0% byproduct 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 byproducts. Producers may also feed levels as high as 75% without negatively affecting performance. However, optimum inclusion rates of a byproduct 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 byproducts in the diet, are removed and replaced with corn abruptly. Therefore, one approach would be to feed a combination to ensure that at least one byproduct is consistently in the ration.

Table 5. 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^{a}	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.

NEW ETHANOL INDUSTRY BYPRODUCTS

The evolving ethanol industry is continually striving to maximize ethanol production efficiency. Changes associated with this progress will provide innovative new byproduct feeds for producers to utilize. One example of a new byproduct feed is Dakota Bran Cake (DBRAN). DBRAN is a distillers byproduct feed produced as primarily corn bran plus distillers solubles produced from a hybrid wet and dry milling process. On a DM basis, DBRAN 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 DBRAN ration inclusion up to 45% DM by comparing 0, 15, 30, and 45% DBRAN. Results indicated improved final weight, ADG, DMI and F:G compared to feeding a blend of high-moisture and dry-rolled corn, suggesting DB has 100 – 108% of the energy value of corn. DBRAN is only one example of how new ethanol industry byproducts will feed relative to traditional finishing rations. Each new byproduct 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 byproducts produced.

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