2007

Utilization of Corn Co-Products in the Beef Industry: Feeding of Corn Milling Co-Products to Beef Cattle

Galen E. Erickson
University of Nebraska-Lincoln, gerickson4@unl.edu

Virgil R. Bremer
University of Nebraska-Lincoln, vbremer2@unl.edu

Terry J. Klopfenstein
University of Nebraska-Lincoln, tklopfenstein1@unl.edu

Leslie Aaron Stalker
University of Nebraska-Lincoln, stalkera@byui.edu

Richard J. Rasby
University of Nebraska-Lincoln, rrasby1@unl.edu

Utilization of Corn Co-Products in the Beef Industry

2nd Edition • August 2007

NEBRASKA CORN BOARD

University of Nebraska Lincoln

A joint project of the Nebraska Corn Board and the University of Nebraska–Lincoln Institute of Agriculture and Natural Resources

UTILIZATION OF CORN CO-PRODUCTS IN THE BEEF INDUSTRY

NEBRASKA CORN BOARD

IANR

A joint project of the Nebraska Corn Board
and the
University of Nebraska–Lincoln
Institute of Agriculture and Natural Resources
Agricultural Research Division
University of Nebraska–Lincoln Extension

For more information or to request additional copies of this manual,
contact the Nebraska Corn Board at 1-800-632-6761 or e-mail k.brunkhorst@necorn.state.ne.us.

Brought to you by Nebraska corn producers through their corn checkoff dollars—expanding demand for Nebraska corn and value-added corn products.

FEEDING OF CORN MILLING CO-PRODUCTS TO BEEF CATTLE

Galen E. Erickson, Virgil R. Bremer, Terry J. Klopfenstein, Aaron Stalker, and Rick Rasby

Department of Animal Science
University of Nebraska–Lincoln

Corn milling co-products are expected to increase dramatically in supply as the ethanol industry expands. Distillers grains, corn gluten feed, or a combination of both co-products offer many feeding options when included in pasture and feedlot diets. These co-product feeds may effectively improve cattle performance and operation profitability. When these co-products are fed in feedlot diets, adjustments to grain processing method and roughage level may improve cattle performance. Innovative storage methods for wet co-products and the use of dried co-products offer small operations flexibility when utilizing co-products. As new co-products are developed by ethanol plants, they should be evaluated with performance data to determine their product-specific feeding values.

INTRODUCTION

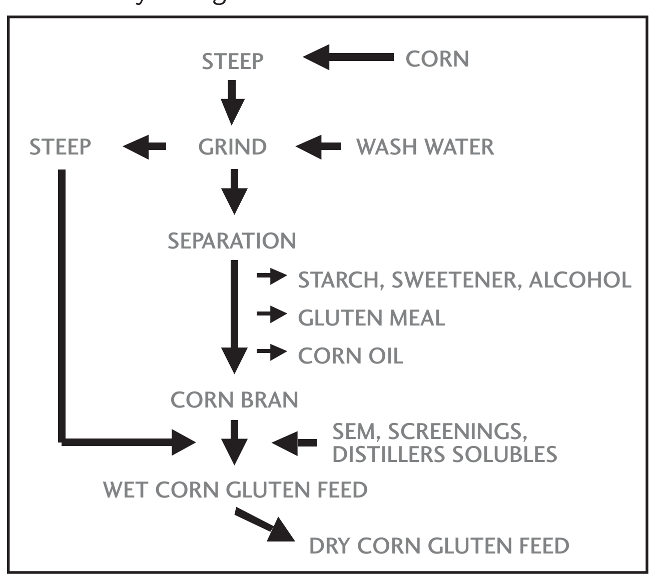
Two primary types of milling processes currently exist, resulting in quite different feed products. The dry milling process produces distillers grains plus solubles (DGS), and the wet milling process produces corn gluten feed (CGF). These feeds can be marketed as wet feeds, or they can be dried and marketed as either dry corn gluten feed (DCGF) or dry distillers grains (DDG) with or without solubles.

For the purposes of this article, wet corn gluten feed (WCGF), wet distillers grains plus solubles (WDGS), DCGF, and dried distillers grains plus solubles (DDGS) will be discussed. The term DGS will be used for undifferentiated discussion about WDGS and DDGS. The majority of ethanol plant expansions are dry milling plants that produce DGS; however, an increase in supply of WCGF is also expected. Therefore, these feeds may be very attractive for beef producers to use as feed sources. This article will focus on the production, composition, feeding values, and economics of using these co-products in feedlot and forage situations. Management strategies will be discussed as well, including grain processing and roughage levels when these co-products are used in feedlot diets, feeding combinations of WDGS and WCGF, and manure management. Forage fed situations will be covered primarily with dried co-products as this is a common application for both energy and protein supplementation in many forage feeding situations. Storage methods for wet products and manure management from co-products feeding will also be explained.

Wet Milling

Wet milling is a process that requires use of high quality (U.S. No. 2 or better) corn that fractionates the corn kernel to produce numerous products intended for human use. Fresh water enters the milling system in the final stage of starch washing. Subsequently, it runs countercurrent with respect to the flow of corn, passing through numerous screens and separating implements, acquiring soluble nutrients at each step. Ultimately, this solution will serve as the resource in which corn entering the process will be initially steeped. Lactic acid-producing bacteria in the steeping process ferment the soluble carbohydrates collected by the water to further kernel softening. Following the steeping process (Figure 1), corn kernels are separated into kernel components of corn bran, starch, corn gluten meal (protein), germ, and soluble components. If the wet milling plant is fermenting starch into ethanol, a portion of the steep water (now called steep liquor) is added to the fermentation vats to supply nutrients for the ethanol-producing yeast cells to grow. The ethanol is distilled off after the fermentation process. The solution exiting the still is called distillers solubles, not to be confused with dry milling distillers solubles. This product contains very little corn residue, almost no fat, and is high in protein from the remnants of yeast cells from the fermentation process. The distillers solubles and a portion of the steep liquor are added to the bran fraction of the corn resulting in WCGF. The WCGF can have a portion of the 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). The actual composition of WCGF can vary depending on the plant capabilities. Steep, a combination of steep liquor and distillers solubles, contains more energy (136% the feeding value of corn) and protein than corn bran or germ meal (Scott et al., 1997). Therefore, plants that apply more steep to corn bran or germ meal will produce WCGF that is higher in crude protein (CP) and energy.

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

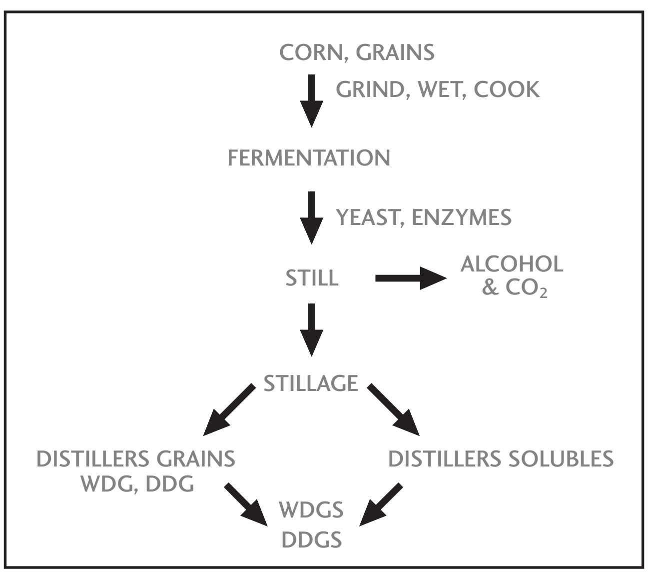


WCGF contains 16 to 23% CP, which is approximately 70% ruminally degradable protein (degradable intake protein, DIP) used by rumen microbes. During wet milling, corn gluten meal is removed and marketed in higher value markets. Corn gluten meal should not be confused with WCGF, as corn gluten meal contains approximately 60% CP that is 40% DIP and 60% bypass protein (undegradable intake protein, UIP).

Dry Milling

The dry milling ethanol process (Figure 2) is relatively simple. Corn (or another starch source) is ground, fermented, and the starch converted to ethanol and CO^2. Approximately 1/3 of the dry matter (DM) remains as feed product following starch fermentation, assuming the 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. In the dry milling process, the resultant feed co-products are distillers grains, distillers solubles, and distillers grains plus solubles depending on the plant and whether it is producing wet or dry co-products, and the relative amounts of distillers grains and distillers solubles mixed together. If all of the solubles are added back to the grains, DGS are approximately 80% distillers grains and 20% distillers solubles (DM basis) (Corrigan et al., 2007a). Most distillers grains contain some solubles, but this can vary from plant to plant. Solubles are a good source of protein, high in fat, phosphorus (P), and sulfur (S) and low in fiber (Corrigan et al., 2007a). Solubles contain 25% CP, 20% fat, 1.57% P, 0.92% S, and 2.3% neutral detergent fiber (NDF). Distillers solubles have become a popular base for liquid feed supplements. As molasses prices have increased, liquid supplement companies are using wet milling industry steep and dry milling distillers solubles in place of molasses for liquid supplements. In addition, solubles may replace corn and protein in finishing diets (Trenkle, 1997b). Steers fed 4 or 8% of diet DM as corn distillers solubles had improved feed conversion compared to steers fed a conventional cracked corn diet.

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



The wet milling industry is more complex than dry milling in that the corn kernel is divided into more components for higher value marketing in wet milling. 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.

Composition

Table 1 contains data on production plant averages for various corn milling co-products. Variation exists from plant to plant and even within a given plant. These table values should not replace sampling and analysis of feed from individual plants. The DDGS, WDGS, and condensed corn distillers solubles (CCDS) are all from one plant in Nebraska and represent average values for 2003.

Table 1. 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	44.7	60.0	90.4	34.9	35.5	46.2	49.4
CP, % of DM	9.8	19.5	24.0	33.9	31.0	23.8	30.6	35.1
UIP, % of CP	60	20	20	65	65	65	65	20
P, % of DM	0.32	0.66	0.99	0.51	0.84	1.72	0.84	1.92
NEg[e], Mcal/lb	0.70	0.70	0.76	0.82	0.91	0.87	NA	0.95

[a] DRC=dry rolled corn with NRC (1996) values, WCGF-A = wet corn gluten feed, WCGF-B = Cargill Sweet Bran wet corn gluten feed, DDGS = dried distillers grains plus solubles, WDGS = wet distillers grains plus solubles, CCDS=condensed corn distillers solubles (corn syrup), MWDGS=modified wet distillers grains plus solubles, steep is steep liquor from wet milling plants.

[b] DRC values based on NRC (1996) values with approximately 3,500 samples.

[c] Values are from spring, 2003 from only one plant in Nebraska that produces DDGS, WDGS, and CCDS.

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

[e] Net Energy-Gain (NEg) values are based on animal performance relative to DRC. WDGS and DDGS NEg values are dependent on dietary inclusion.

Examples of plants with an excellent database on variability are the Cargill facilities in Blair (NE), Eddyville (IA), and Dalhart (TX). The standard deviations are low on DM change from load to load. This relates to two things: process development to minimize variation and the quality control culture of personnel operating the plants to minimize variation in feed products. The energy values used in Table 1 are based on performance data summarized in this paper and other reviews.

The DDGS composition data in Table 2 are based on the relative ratios of dried distillers grains to solubles ratio in DDGS (Corrigan et al., 2007a). The ethanol plant's normal DDGS averaged 19% solubles. However, in this study distillers grain products were produced with 0 to 22% solubles added back to the grain portion. Increasing the amount of solubles decreased the DM, CP, and NDF content of the DDGS. However, the fat level increased in the DDGS as more solubles were added. As more solubles were added back from 0 to 22%, the resulting DDGS went from a golden yellow color to a brown color. However, the change in color was not related to total digestive tract protein digestibility as the protein was 97 to 98% digestible in all samples. For another recent review of composition and variation within plants and across plants, the reader is referred to Holt and Pritchard (2004). Moisture and DM variation are probably of greatest importance with wet co-products.

However, both fat and sulfur levels can vary in DGS, which could lead to changes in feeding value and potential for toxicity (especially polioencephalomalacia), respectively. Based on preliminary results from a sampling experiment, wet distillers grains average approximately 0.7 to 0.8% sulfur. Therefore, it is critical to have accurate analyses on feed ingredients, a sulfur analysis of water that cattle are drinking, and then formulation of diets not exceeding approximately 0.4% (NRC, 1996). Thiamine is commonly added at 150 to 200 mg/steer daily as well to offset challenges related to sulfur-induced polio. This is an important issue to be aware of and to treat cattle as quickly as possible if any symptoms from polio are observed.

Table 2. Nutrient composition and protein digestibility of DDGS based on solubles level

	Solubles Level[a], % of DDGS mix (DM)				
Item	**0**	**5.4**	**14.5**	**19.1**	**22.1**
DM, %	95.5	92.1	90.8	89.3	89.6
CP, %	32.1	31.9	31.5	30.7	30.9
Fat, %	6.9	8.9	10.4	12.7	13.3
NDF, %	36.8	34.9	31.9	30.3	29.3
CP Digestibility[b]	97.2	97.4	97.9	97.9	97.9

[a] Solubles level calculated using % NDF of solubles (2.3%) and 0% solubles DDG.
[b] In situ total-tract protein digestibility.

USE IN FEEDLOT CATTLE

Feeding Value

The first units of co-products added to a ration are primarily used to replace protein from urea or natural protein sources in the ration. Subsequent additions of co-products to the ration replace corn and other grains as energy sources. Feedlot diets that use DGS at levels less than 15 to 20% of diet DM serve as a protein source for the animal. Conversely, when DGS is added above these levels, the beef animal utilizes the DGS as an energy source.

The feeding value of DGS and CGF is dependent on whether the co-products are fed wet or dry and the level of dietary inclusion. Although the feeding value of WCGF is better than corn (100 to 112% the feeding value of corn), the feeding value of DCGF is 88% of dry rolled corn (DRC) when fed at 25 to 30% of diet DM (Green et al., 1987; Ham et al., 1995).

The majority of the research on distillers grains as a feed source has been conducted on finishing cattle. Experiments evaluating the use of wet distillers co-products in ruminant diets are available (Buckner et al., 2007a; Corrigan et al., 2007b; DeHaan et al., 1982; Fanning et al., 1999; Farlin, 1981; Firkins et al., 1985; Larson et al., 1993; Luebbe et al., 2007; Trenkle, 1997a; Trenkle, 1997b; Vander Pol et al., 2004; Vander Pol et al., 2005a). Feeding WDGS results in better performance than DDGS (Table 3).

Table 3. Feeding value of wet vs. dry distillers grains (Ham et al., 1995).

		WDGS	**DDGS**		
	Control		**Low[a]**	**Medium[a]**	**High[a]**
Daily feed, lb	24.2^{bc}	23.6^{b}	25.3^{c}	25.0^{cd}	25.9^{d}
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 (avg.)…………		
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)

Figure 3 – Feed conversion of feedlot cattle fed diets containing wet distillers grains plus solubles when replacing corn at different inclusions

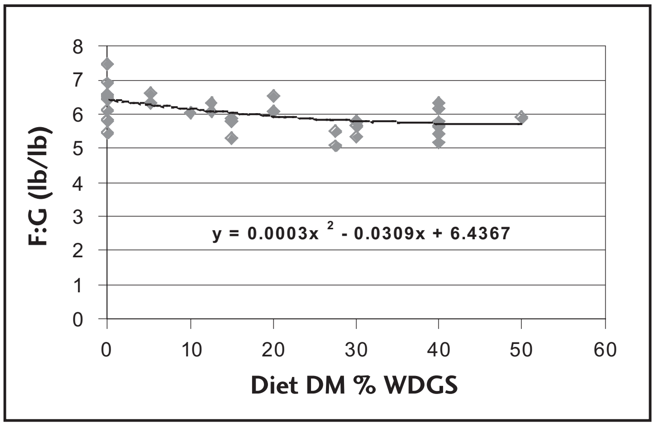
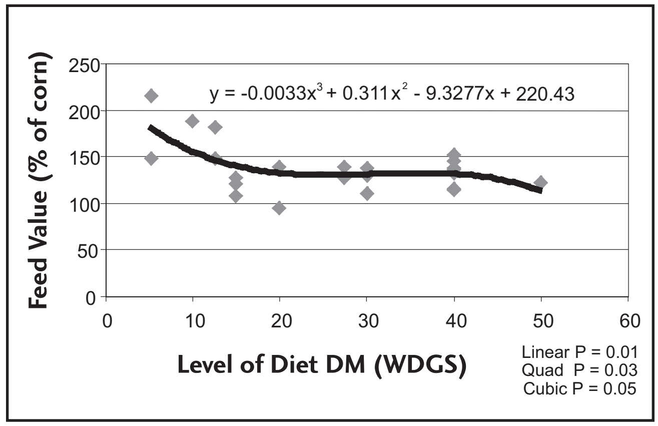


Figure 4 – Feeding value of wet distillers grains plus solubles when replacing corn at different inclusions



In studies with finishing cattle, the replacement of corn grain with WDGS consistently improved feed efficiency (Figure 3). Figure 4 summarizes University of Nebraska studies conducted on WDGS with feeding value expressed relative to corn. The feeding value of WDGS is consistently higher than corn. These studies suggest a 31 to 43% improvement in feed efficiency when WDGS replaces intermediate levels of DRC (15 to 40% of diet DM). The WDGS replaced corn in the diet. The feeding value at low levels (less than 15%) is approximately 145% the feeding value of corn. When higher levels of WDGS are used (greater than 40%), the feeding value was still greater than corn. Replacing DRC with WDGS results in a quadratic improvement in average daily gain (ADG) (Figure 5). The optimal biological response in ADG was at 30% WDGS inclusion.

Huls et al. (2008) evaluated modified distillers grains plus solubles (MDGS; 42 to 48% DM) at 0, 10, 20, 30, 40, and 50% of diet DM, which is potentially different than traditional WDGS (32 to 35% DM) because it is partially dried. Carcass adjusted final body weight (BW) and ADG responded quadratically ($P < 0.01$) as MDGS inclusion increased (Table 4). Cattle fed 20% MDGS produced the greatest ADG. Feed conversion improved linearly ($P < 0.01$) with optimum conversion seen when cattle were fed 50% MDGS. Calculated feeding value of MDGS relative to HMC/DRC was highest for 10% MDGS and decreased as MDGS treatment increased to 50% of diet DM (123 to 109% the feeding value of corn, respectively). Carcass weight and USDA calculated Yield Grade responded quadratically ($P < 0.05$) as MDGS inclusion increased in the diet with 20% MDGS cattle having the heaviest carcasses and greatest Yield Grade. Daily gain was greatest

Figure 5 – Average daily gain of feedlot cattle fed diets containing wet distillers grains plus solubles when replacing corn at different inclusions

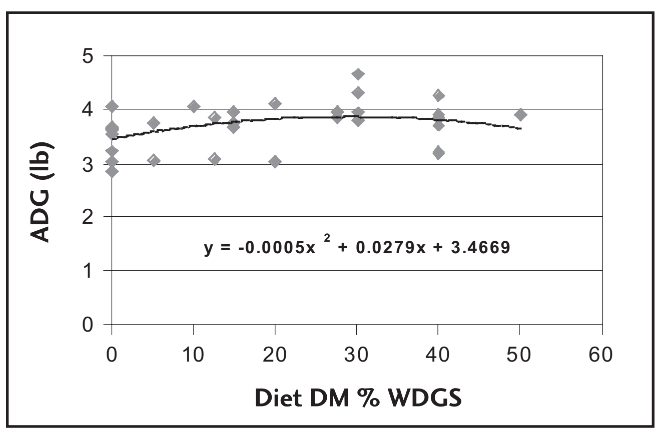


Table 4. Calf-fed steer finishing feedlot performance when fed varying levels of modified wet distillers grains plus solubles[a]

	CON	10MDGS	20MDGS	30MDGS	40MDGS	50MDGS	SEM	Lin[b]	Quad[c]
Performance									
Initial BW, lb	748	749	748	745	747	748	27	0.32	0.32
Final BW[d], lb	1395	1411	1448	1439	1418	1398	38	0.82	<0.01
DMI, lb/day	23.0	23.1	23.5	23.2	22.8	21.6	0.7	0.03	0.01
ADG, lb	3.67	3.75	3.97	3.94	3.81	3.69	0.10	0.73	<0.01
F:G[e]	6.23	6.11	5.90	5.87	5.94	5.82		<0.01	0.28
Carcass Characteristics									
HCW, lb	879	889	912	906	893	881	24	0.82	<0.01
Marbling Score[f]	520	513	538	498	505	490	17	0.10	0.42
12th Rib Fat, in	0.57	0.57	0.61	0.62	0.57	0.54	0.04	0.54	0.12
LM Area, in^2	12.8	12.5	12.8	12.8	12.7	12.7	0.2	0.98	0.97
Calculated Yield Grade[g]	3.68	3.91	3.92	3.91	3.84	3.64	0.17	0.69	0.04

[a] Dietary treatment levels (DM basis) of MDGS, CON= Control (0% MDGS), 10MDGS= 10% MDGS, 20MDGS= 20% MDGS, 30MDGS= 30% MDGS, 40MDGS= 40% MDGS, 50MDGS= 50% MDGS.
[b] Contrast for the linear effect of treatment P-Value.
[c] Contrast for the quadratic effect of treatment P-Value.
[d] Calculated from hot carcass weight, adjusted to a 63% yield.
[e] Calculated from total gain over total DMI, which is reciprocal of F:G.
[f] 450 = Slight 50, 500 = Small 0.
[g] Where yield grade = 2.5 + 2.5(Fat thickness, in) – 0.32(LM area, in^2) + 0.2(KPH fat, %) + 0.0038(hot carcass weight, lb).

Table 5. Performance measurements for cattle fed increasing levels of DDGS[a]

Parameter	CON	10DDGS	20DDGS	30DDGS	40DDGS
DMI, lb	20.8	21.8	20.8	21.2	20.7
ADG[b], lb	3.29	3.55	3.71	3.56	3.56
F:G[c]	6.32	6.15	5.60	5.93	5.77
Feed Value[bd], %	---	124	126	108	108

[a] CON = Control (0% DDGS), 10DDGS = 10% DDGS, 20DDGS = 20% DDGS, 30 DDGS = 30% DDGS, 40DDGS = 40% DDGS.
[b] Quadratic response to level of DDGS in the diet (P = 0.08).
[c] Linear response to level of DDGS in the diet (P = 0.07).
[d] Calculated with iteration process for net energy calculation based on performance.

at 20 to 30% MDGS inclusion, and feed to gain (F:G) was lowest at 40 to 50% MDGS dietary inclusion. Therefore, we would recommend feeding 20 to 40% of diet DM as modified wet distillers grains plus solubles to optimize performance. Buckner et al. (2007d) conducted a 145-day feedlot finishing study to evaluate 0, 10, 20, 30, and 40% dietary DM inclusion of DDGS in corn-based diets on steer performance. There was a quadratic response in performance. The 20% DDGS diet had the most improved performance when compared to a corn-based diet, with a feeding value of 126% the value of corn (Table 5). However, all DDGS levels had improved F:G and feeding value relative to the corn control diet. The biological optimum level of DDGS to feed with DRC and high moisture corn (HMC) is less than with WDGS. The biological optimum levels for the dry and wet DGS are 20 and 30-40%, respectively.

Experiments evaluating the use of WCGF replacing DRC or HMC in feedlot diets are available (Buckner et al., 2007a; Herold et al., 1998; Loza et al., 2007; Richards et al., 1995; Scott et al., 2003; Scot et al., 1997).

Figure 6 – Feed conversion of feedlot cattle fed diets containing wet corn gluten feed when replacing corn at different inclusions

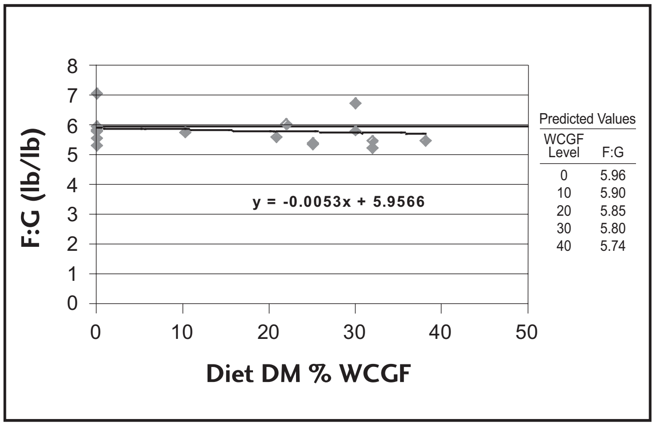
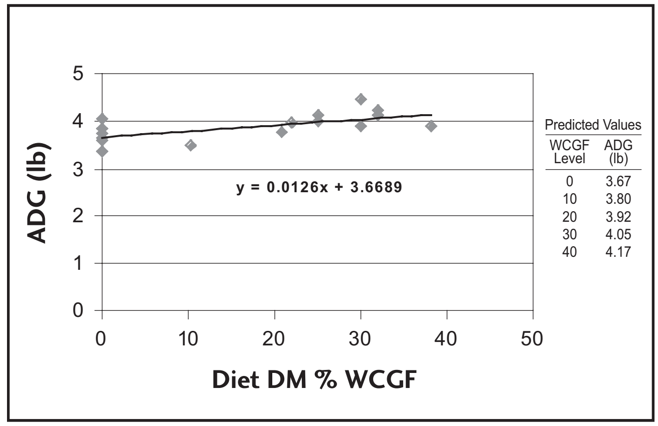


Figure 7 – Average daily gain of feedlot cattle fed diets containing wet corn gluten feed when replacing corn at different inclusions



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. Based on differences in the amount of steep added, WCGF has 100 to 109% the feeding value of DRC when fed at levels of 20 to 60% of diet DM (Stock et al., 1999). The higher feeding value (and protein) is associated with increases in steep added in WCGF. Feeding WCGF results in better performance than DCGF (Ham et al., 1994). In studies with finishing cattle, the replacement of corn grain with WCGF consistently improved feed efficiency (Figure 6). Replacing DRC with higher feeding value WCGF in feedlot diets will linearly improve ADG (Figure 7).

The improved animal feeding performance from co-product feeds translates into improved quality grade for steers fed co-products compared to grain. (Bremer et al., 2007). Since the co-product diets have improved feeding values relative to corn, the cattle gain weight quicker than corn

Figure 8 – Backfat thickness of feedlot cattle fed diets containing wet distillers grains plus solubles when replacing corn at different inclusions

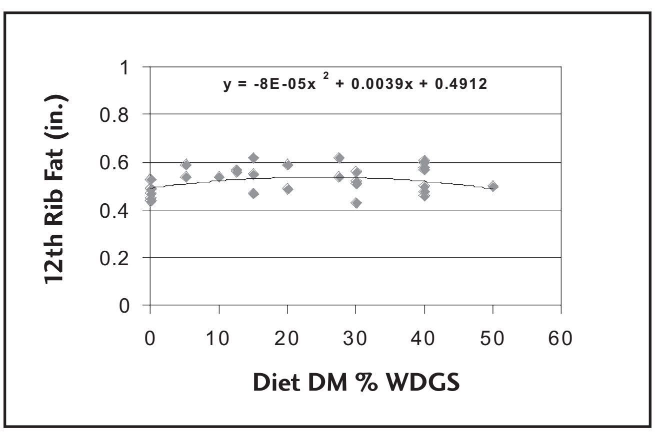


Figure 9 – Backfat thickness of feedlot cattle fed diets containing wet corn gluten feed when replacing corn at different inclusions

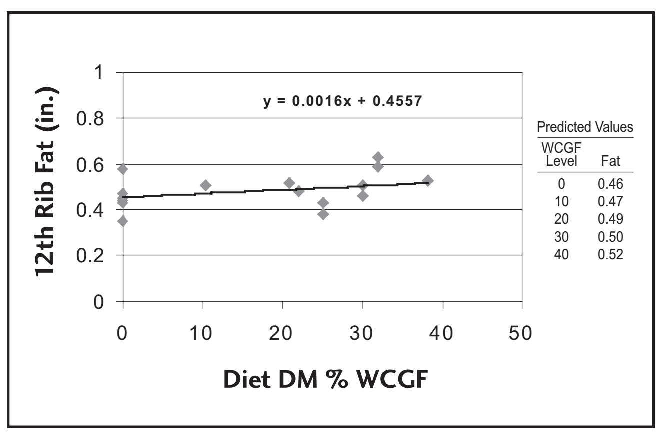


Figure 10 – Marbling score of feedlot cattle fed diets containing wet distillers grains plus solubles when replacing corn at different inclusions

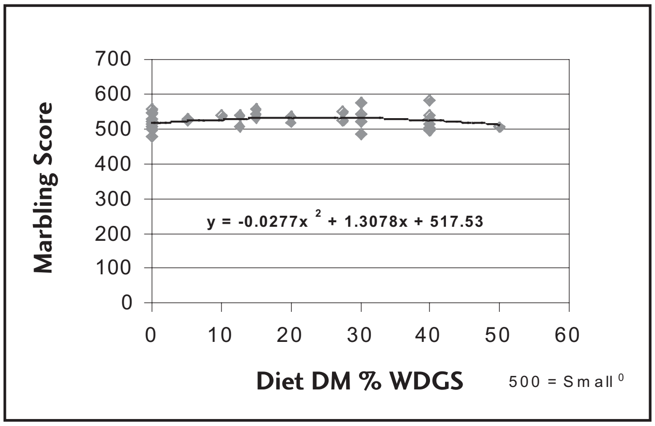
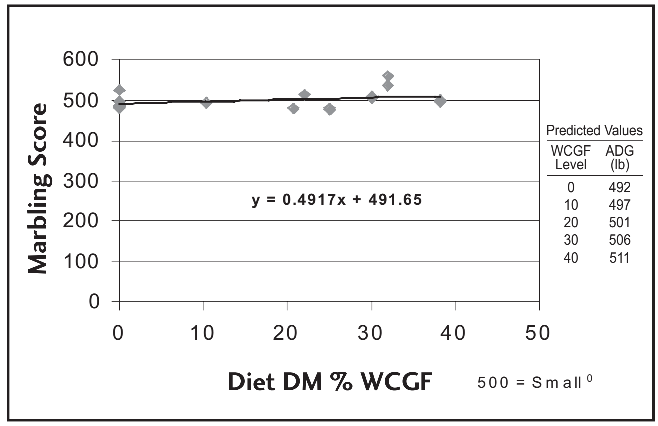


Figure 11 – Marbling score of feedlot cattle fed diets containing wet corn gluten feed when replacing corn at different inclusions



fed feedlot cattle. Therefore, these cattle require fewer days on feed to reach the same backfat and marbling endpoints. Co-products-fed cattle consuming intermediate levels (10 to 40% diet DM) of WDGS or WCGF for the same number of days on feed (DOF) as conventional corn fed cattle will be slightly fatter (Figures 8 and 9) and have more marbling than corn-fed cattle (Figures 10 and 11). The improved marbling is due to improved daily gains. Feeding diets that help cattle fatten more rapidly (i.e. co-products diets) will improve the Quality Grade of feedlot cattle.

In certain production situations, light weight (less than 750 lb) finishing cattle may need to be supplemented with UIP (bypass) protein to meet metabolizable protein (MP) requirements. Wet or dry DGS is an excellent source of UIP. The values obtained from feeding trials for UIP are shown in Table 6. Wet grains were compared to dry grains and the value of the protein was similar (Table 7). This suggests that the high escape protein value of DGS 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.

Dry distillers grains contain approximately 65% UIP (% of CP), consequently diets that include dried distillers grains fed as an energy source are commonly deficient in

Table 6. Escape protein values

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

Table 7. Wet and dry distillers 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] ADIN.

degradable intake protein (DIP) but contain excess MP. Cattle convert excess MP to urea, which is potentially recycled to the rumen and can serve as a source of DIP. Vander Pol et al. (2005b) fed DDGS 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. However, some numerical differences suggested a conservative approach would be to follow NRC (1996) guidelines for DIP supplementation if DGS are provided at less than 20% of diet DM.

Interaction of corn processing and co-products feeding

Feeding corn milling co-products in feedlot diets reduces acidosis-related challenges. Both WCGF and WDGS have little to no starch remaining following the milling process. Therefore, feeding these co-products will dilute whatever starch is fed and influence rumen metabolism. Krehbiel et al. (1995) observed a decrease in subacute acidosis when WCGF was fed to metabolism steers. In many studies, feeding WCGF resulted in increased dry matter intake (DMI), which would be a common response to less subacute acidosis.

Because processing corn increases the rate of digestion by microbes, rumen acid production is increased and the risk of acidosis is increased (Stock and Britton, 1993). Feeding 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 feeding values are markedly improved in diets containing WCGF when corn is more intensely processed. Scott et al. (2003) evaluated various corn processing techniques and observed improved feed conversions as processing intensity increased when feeding calves or yearlings (Table 8). Ranking of processing based on feed conversions (lowest to highest) was whole corn, DRC, HMC, and steam-flaked corn (SFC) when fed to finishing calves. Relative improvements in F:G for DRC, HMC and SFC compared to whole corn were 6.8, 11.1 and 12.5%, respectively. When fed to yearlings, response to processing

Table 8. Effect of corn processing when fed with wet corn gluten feed (Macken et al., 2006, Scott et al., 2003)

25% WCGF					
Processing[a]	**DRC**	**FGC**	**RHMC**	**GHMC**	**SFC**
ADG, lb	4.23	4.35	4.21	4.24	4.33
F:G	5.49[b]	5.29[c]	5.13[d]	5.05[d]	4.90[e]
Fecal starch, %	19.2[b]	11.8[c]	10.60[cd]	8.4[d]	4.1[e]
32% WCGF with calf-feds					
Processing[a]	**Whole**	**DRC**	**FGC**	**RHMC**	**SFC**
ADG, lb	4.18	4.24	4.27	4.15	4.25
F:G	5.95[b]	5.56[c]	5.35[d]	5.29[de]	5.21[e]
22% WCGF with yearlings					
Processing[a]		**DRC**	**FRC**	**RHMC**	**SFC**
ADG, lb		3.98[b]	3.95[b]	4.02[b]	4.22[c]
F:G		6.10[bc]	6.17[b]	5.99[c]	5.52[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 ($P < 0.10$)

Table 9. Effect of corn processing when fed with wet distillers grains

30% WDGS included in all diets

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

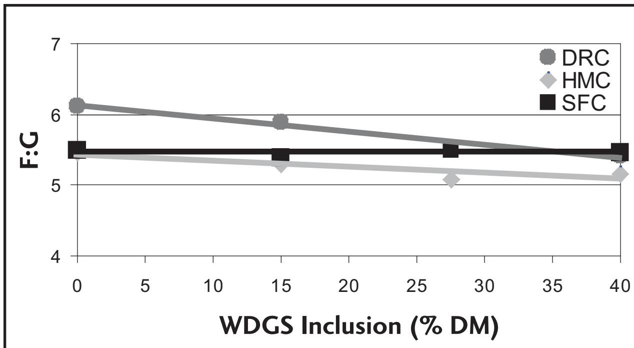
[a,b,c,d] Means with different superscripts differ ($P < 0.05$).
[e] DRC = dry rolled corn, HMC = high moisture corn, SFC = steam flaked corn, whole = whole corn.

was not as favorable as with calves. Feeding HMC did not significantly improve F:G compared to DRC. Macken et al. (2006) fed DRC, SFC, and HMC processed as either rolled (roller mill, RHMC) and ground (tub grinder, GHMC) to calves, with all diets containing 25% WCGF. Whole corn was not fed in this study, but performance was more significantly improved the more intensely the corn was processed. Net energy calculated from performance (NRC, 1996; Owens et al., 2002) was increased by 9.1, 11.0, and 14.9% for RHMC, GHMC, and SFC, respectively, compared to DRC.

HMC appears to have greater feeding value when diets contain WCGF than what was previously observed in diets not containing WCGF. Because HMC has greater ruminal starch digestibility than DRC or SFC (Cooper et al., 2002), cattle fed HMC have a greater potential for acidosis when HMC is fed alone. However, feeding HMC in combination with WCGF appears to increase efficiency of utilization of HMC, perhaps by reducing acidosis. For example, the feeding value of HMC in diets containing HMC as the only grain source is lower than that observed when fed in combination with other grains (Stock et al., 1991) or corn co-products. 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, optimal corn processing in diets containing WDGS appears to be somewhat different than diets containing WCGF. Vander Pol et al. (2006) fed diets containing 30% WDGS with either whole, DRC, HMC, a 50:50 blend of HMC and DRC (DM basis), or SFC to finishing steers for 168 days. Cattle fed DRC, HMC, or a combination of HMC and DRC gained more and were more efficient than cattle fed whole corn (Table 9). Interestingly, cattle fed SFC did not gain as efficiently. Corrigan et al. (2007b) investigated feeding DRC, HMC, or SFC in diets containing 0, 15, 27.5 or 40% WDGS. They found greater performance response to WDGS inclusion in diets based on DRC and HMC (Figure 12). Optimal ADG, and F:G were seen with 40% WDGS in DRC based diets, 27.5%

Figure 12 – F:G of WDGS with different corn processing types[ab]



[a]Linear effect of WDGS within DRC ($P < 0.01$).
[b]Linear effect of WDGS within HMC ($P < 0.05$).

WDGS in HMC based diets, and 15% WDGS in SFC based diets. In addition, when diets contained 40% WDGS with DRC the cattle performed just as efficiently as cattle on the SFC diets. A greater performance response to WDGS inclusion in diets based on less intensely processed grain may render them an economically attractive alternative to diets based on more intensely processed grains. It is unclear why steam flaking did not improve performance when diets contained WDGS at inclusion levels similar to WCGF inclusion levels.

Interaction of roughage and co-products feeding

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). There was a significant interaction between WCGF and alfalfa level for feed conversion; therefore, only simple effects are presented in Table 10. 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 in DRC-based diets that contain 35% or more WCGF. The ADG was reduced for the 0% hay, 35% WCGF treatment, so a small amount of roughage is recommended even when WCGF is included. 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.

Benton et al. (2007) fed alfalfa hay, corn silage, or corn stalks as the roughage source in 30% WDGS (DM basis) diets. Each of the sources was included at a conventional level and one-half that level (Table 11). The normal level was equal to 8% alfalfa hay and the low level was equal to 4% alfalfa hay. In general, normal roughage levels increased DMI, ADG, and profit. However, steers fed 3% corn stalks performed similarly to steers fed normal levels of roughage. When roughage was eliminated from the 30% WDGS diets, DMI, ADG, and profit were decreased compared with diets containing cornstalks or normal levels of alfalfa or corn silage. Therefore it is not beneficial to completely eliminate roughage sources from finishing diets containing 30% WDGS (DM basis).

Table 10. 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
F:G[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 11. Effects of roughage source and level compared to no roughage inclusion on performance of steers fed diets containing 30% WDGS

Treatments:[a]	CON	LALF	LCSIL	LCSTK	NALF	NCSIL	NCSTK
Roughage Inclusion [b]	0.0	4.0	6.1	3.0	8.0	12.3	6.1
DMI, lb	22.3[w]	24.4[x]	24.3[x]	25.0[xy]	25.7[y]	25.3[y]	25.6[y]
ADG, lb	4.33[w]	4.54[wx]	4.52[w]	4.79[y]	4.76[xy]	4.75[xy]	4.80[y]
F:G	5.14	5.37	5.36	5.20	5.41	5.33	5.32
Profit over CON, $ [c]	0[w]	9[wx]	9[wx]	31[y]	23[xy]	27[xy]	29[y]

[a] CON = Control, LALF = low alfalfa hay, LCSIL = low corn silage, LCSTK = low corn stalks, NALF = normal alfalfa hay, NCSIL = normal corn silage, and NCSTK = normal cornstalks.
[b] Inclusion level of each roughage source in the finishing diet (DM basis).
[c] Profit: treatment final steer profit accounting for initial steer cost, health cost, yardage, interest and death loss minus control finished steer profit.
[w,x,y,z] Means in a row with unlike superscripts differ (P<0.05).

Wet co-products allow the use of lower quality roughages because they contain considerable protein and because the moisture minimizes sorting of all ingredients, especially the lower quality roughages. The lower quality roughages have higher fiber contents so diets should be formulated on the basis of their fiber content. Small amounts of roughage, equal to 3 to 4% alfalfa hay, should be included in diets with wet co-products to ensure good levels of DMI and ADG.

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 concurrently. In addition to their commercial availability, another reason for feeding a combination of WDGS and WCGF is their nutritional profiles. Complementary effects in feeding a combination of these co-products might be expected 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 of 0, 25, 50, and 75% DM. All inclusion levels of the blend were evaluated with 7.5% alfalfa hay in the diets. 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

Table 12. 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.

were no differences in cattle performance between forage levels for each co-products blend level. The lack of differences in performance with decreasing forage would indicate that the co-products inclusion was enough to prevent the negative consequences of sub-acute acidosis (Table 12). The analysis of the pooled data from each co-products level indicated that the performance of the steers fed the maximum co-products level (75%), regardless of the forage level, was not different than a typical corn-based diet (0% co-products blend). However, the diets including a 25 and 50% blend of WDGS and WCGF resulted in significantly better animal performances than the control.

Buckner et al. (2007a) fed the same combination at 30 or 60% dietary DM compared to feeding the co-products alone at 30% dietary DM or a 0% co-products diet. The 30% WDGS diet gave the best performance. However, feeding WCGF or WDGS in a blend (1:1 DM basis) or alone improved performance over control fed cattle. A second trial by Loza et al. (2005) compared a 0% co-products diet to six other diets containing a constant amount of WCGF (30% diet DM) and additions of WDGS at 0, 10, 15, 20, 25 or 30% diet DM. Including WDGS at 15 to 20% of the diet with 30% WCGF had the greatest ADG. This research agrees with Buckner et al. (2007a) in that the 30% WCGF plus 30% WDGS gave better performance than the corn-based control diet. These three studies demonstrate that high levels of co-products, when fed in combination, can be fed to feedlot cattle without reducing performance compared to corn-based control diets.

Feeding a combination of WDGS and WCGF can also serve as a management tool. A major challenge facing some ethanol plants is not having co-products available for cattle feeders on a consistent basis. Cattle do not respond well if either WDGS or WCGF, as a sole co-product 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 co-product is consistently in the ration.

Economics

An economic model has been developed for determining economic returns when feeding co-products in corn-based finishing diets (Buckner et al., 2007b). Performance responses from University of Nebraska feedlot research trials were used to predict DMI, F:G, and ADG. User defined inputs of cattle prices and weights, co-products inclusion, trucking costs, and yardage costs allow flexibility in generating the expected returns from feeding co-products in a given feeding situation. The base assumptions include:

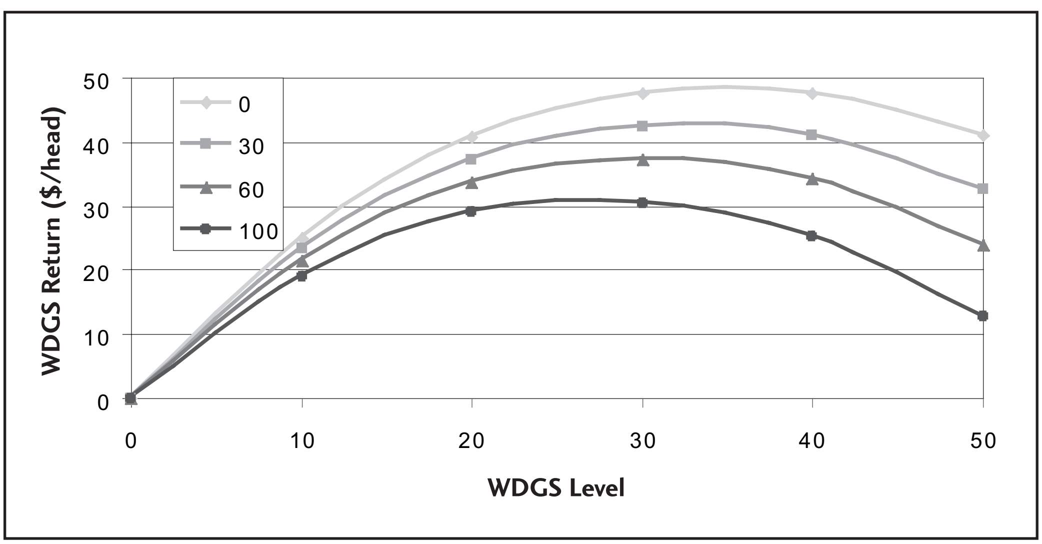


Figure 13 – Economic return from feeding WDGS when fed at 0, 10, 20, 30, 40, or 50% of diet DM at 0, 30, 60, or 100 miles from an ethanol plant

corn price is $3.70, co-products are purchased at 95% the price of corn on a DM basis, feedlot cattle are fed a base ration containing DRC and HMC, and steers are gaining 560 lb over the finishing period. This model suggests the optimum level of WDGS is 30 to 40% of diet DM when feedlots are within 30 miles of the ethanol plant (Figure 13). As the distance increases from the plant to the feedlot, the optimum inclusion of WDGS decreases to 25 to 35%. This comparison suggests that more WDGS can be fed than levels currently being fed; however, the optimum inclusion is dependent on more than just the feeding value of WDGS.

Modeling DDGS with $3.70 corn has a response curve similar to the WDGS curve at 60 miles; however, the economic optimum appears to be at approximately 20% dietary inclusion of DDGS (Figure 14). This is lower than the optimum inclusion for WDGS with the same assumptions. The increase in economic returns from feeding DDGS as corn price increases is consistent with similar corn price changes for WDGS and WCGF. The returns from feeding Sweet Bran WCGF increase as the level of WCGF increases in the diet (Figure 15). This response is consistent for feedlots 0 to 100 miles from the plant. These data clearly show that factors such as cattle performance, distance from the plant, and corn price influence the economic optimum inclusion rate of co-products in feedlot rations.

An Excel spreadsheet model, which is called Cattle CODE, is available for download at http://beef.unl.edu under the "by-products feed" section.

Environmental Issues

Animal manure and commercial fertilizers are sources of phosphorus (P) in agricultural runoff that may cause environmental pollution. Including co-products in rations increases the P concentration of diets resulting in greater P in manure. Inclusion of WDGS at 40% diet DM produces a 90% increase in P excretion. Feeding DGS diets that contain elevated levels of dietary P require more astute manure management plans than feeding conventional corn based diets without supplemental P. Traditional manure management programs have been based on crop nitrogen (N) needs. Transitioning to an annual crop P requirement rate will require five times more land to spread manure. However, spreading manure on a four-year P-based crop rate will only require a modest increase in labor, equipment and land cost over traditional annual N-based manure application to crops. The $25 to $48 of cattle profit from feeding

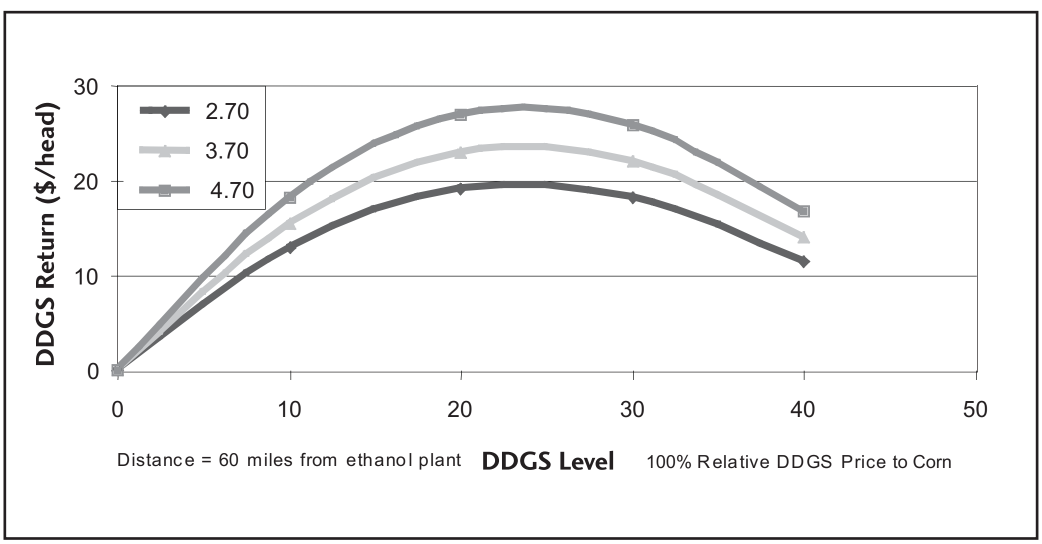


Figure 14 – Economic return from feeding DDGS when fed at 0, 10, 20, 30, or 40% of diet DM 60 miles from an ethanol plant at $2.70, $3.70, or $4.70 per bushel corn

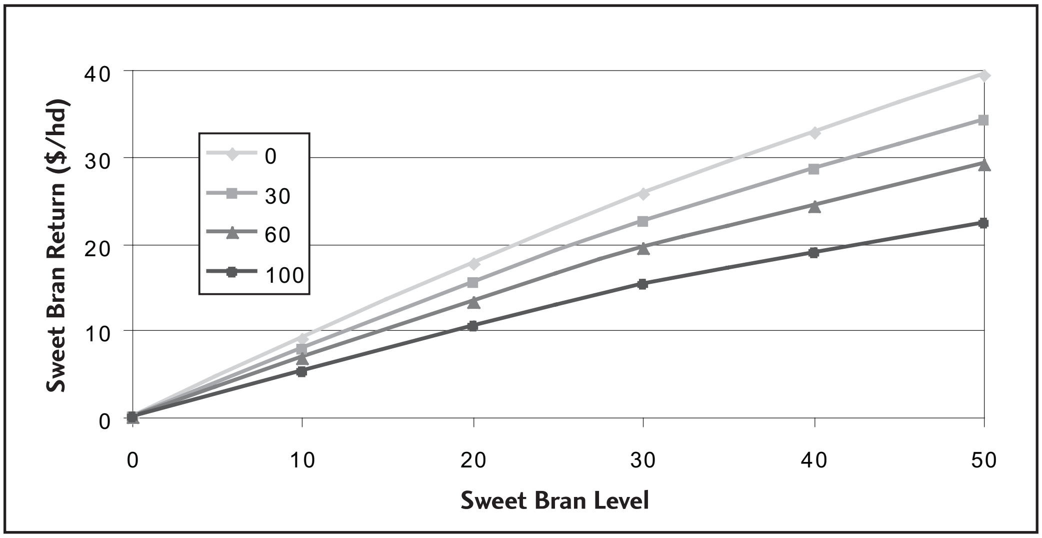


Figure 15 – Economic return from feeding Sweet Bran WCGF when fed at 0, 10, 20, 30, 40, or 50% of diet DM at 0, 30, 60, or 100 miles from an ethanol plant

WDGS occurred at a cost of about $3 to $5 per finished animal from increased manure management costs, depending on feedlot size (Kissinger et al., 2006). However, when the true fertilizer market value is placed on the manure, there is a net profit to manure management. Increases in dietary P level increase the fertilizer value of manure faster than the increase in cost of manure distribution. Accounting for the cost and fertilizer value of the manure, the profit per finished animal from manure management is about $4 per animal. When the WDGS manure management profit is added to the feeding profit from WDGS, the total WDGS profit per animal is $29 to $52 more than a conventional corn-fed animal. This accounting assumes that additional land is readily available on which to spread the manure. Accounting for the manure fertilizer value from DGS fed cattle can actually improve the profitability of cattle feeding operations.

USE IN FORAGE-FED CATTLE

Feeding value

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 CGF were compared to DRC for growing calves fed grass hay, wheat straw, and corn stalklage. The CGF or corn replaced 40% of the forage (Oliveros et al., 1987). The supplements nearly doubled gains and improved feed conversion (Table 13). Wet and dry CGF had better feed conversions than corn, and WCGF had better feed conversion than DCGF. The apparent feeding 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.

Clearly, CGF 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 CGF is an excellent source of protein for microbes. Protein in forages is highly degraded in the rumen. In certain forage situations, light-weight growing cattle may need to be supplemented with UIP to meet MP requirements. Distillers grains (wet or dry) are an excellent source of UIP and phosphorus.

Stocker calves, developing heifers and cows may need energy supplementation in addition to supplemental protein and

Table 13. Wet or dry corn gluten feed or corn in forage-based diets for growing calves[a]

	Forage	Corn	DCGF	WCGF
DMI, lb/day	11.7	18.0	16.4	16.2
ADG, lb	1.16	2.25	2.15	2.36
F:G	10.5	8.01	7.64	6.86

[a]Balanced for 11.5% CP.

phosphorus. It is advantageous if the same commodity can be used for supplemental energy as well as protein. Co-product feeds can be used to supply the energy needs of cattle in pasture and range situations. An additional advantage for DGS and CGF is that these feeds contain very little starch and therefore should not depress fiber digestion in some situations like corn.

Animal performance

Eight grazing experiments were summarized reflecting yearling performance when supplemented with 4.0 or 7.5 lb DDGS (Klopfenstein et al., 2007). Daily gains were increased by 0.53 and 0.89 lb/day, respectively (Figure 16). Subsequent feedlot performance was not influenced by DDGS supplementation on grass. In a six-trial summary, each 1.0 lb of DDGS decreased forage intake by 0.5 lb (Figure 17). Economic returns for each $1.00 spent on DDGS, priced at $120/ton as is in the bunk, yielded returns from $1.41 to $1.94. DDGS may be an attractive forage supplement due to increased revenue from additional ADG and savings from decreased forage intake.

Feeding strategies

An experiment was conducted with 120 crossbred heifers to determine the value of 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 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 14). 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, DDGS daily, DDGS on alternating days, DRC daily, or corn on alternating days (Loy et al., 2004). Hay intake was higher for non-supplemented than for supplemented heifers (Table 15). No intake differences were observed

Figure 16 – ADG response from DDGS supplementation by grazing cattle

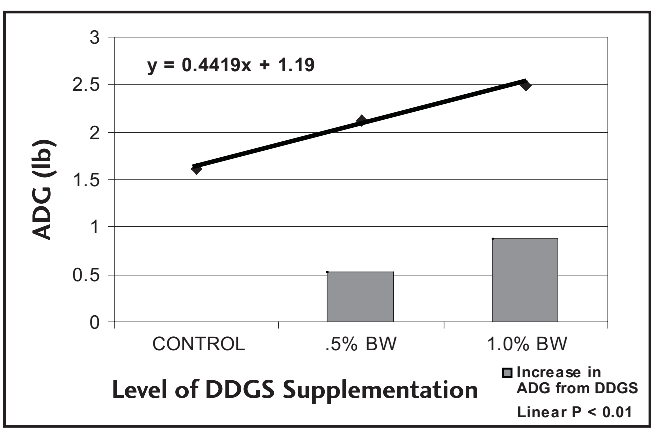


Figure 17 – Reduction in forage intake as DDGS is included in forage diets

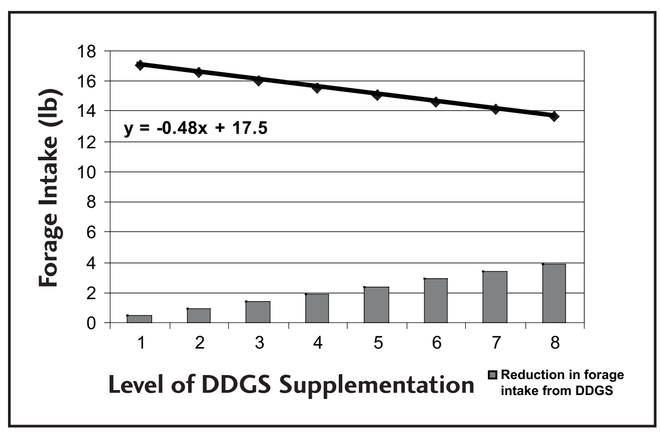


Table 14. Growing calf performance over 84 days when fed native grass hay (CP = 8.7%) supplemented with either corn or DDG for two levels of gain. Net energy was 27% greater for DDG compared to corn (Loy et al., 2003)

		Low[a]	High[a]
ADG, lb/day	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.

between DDGS and 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 digestion than DDGS-supplemented heifers.

Dry DGS contain approximately 65% UIP (% of CP), consequently forage based diets that include dried distillers grains fed as an energy source are commonly deficient in DIP but contain excess 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.

Two experiments evaluated supplemental DIP requirements when DDGS 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 in metabolizable protein. In both experiments, no response in performance was observed when urea was added to the diet (Table 16). Sufficient urea was probably recycled to correct the DIP deficiency. These studies indicate adding urea to meet the DIP requirement is not necessary when DDGS are fed as an energy source in forage-based diets.

Given recent drought conditions in many areas of the U.S. and the price of pasture and hay, 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 has been initiated at the University of Nebraska to address the usefulness and value of dry co-products in cow-calf situations.

Table 15. Treatment effects on intake, neutral detergent fiber disappearance, ruminal pH, and intake pattern (Loy et al., 2004a)

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 plus 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, $P < 0.08$.

Table 16. Performance 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
Individually Fed							
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
Pen Fed							
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

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

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 more than 550 heifers in each group across two years. The TRT utilized only grazed winter forage and DCGF supplementation compared to some winter grazing, with hay and protein supplementation. Performance differences are presented in Table 17; however, no 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., 2006a). Because of the higher energy content of DDGS, a smaller amount was needed to meet protein and energy requirements of these bred heifers (1,353 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.

Feeding DDGS as a supplement to calves grazing winter range results in similar performance and is less expensive than feeding corn and soybean meal supplement. In a two year study, Stalker et al.(2006b) fed steers grass hay (6.6% CP) and 4.4 lbs/day of a corn-soybean meal based supplement in a dry lot (CON), or fed 6.0 lbs/day of the same corn/soybean meal based supplement 6 days/week (CSM), or the daily equivalent of 4.2 lbs/day of a dried distillers grains based supplement either 6 days/week (DDG6) or 3 days/week (DDG3) to steers grazing native winter range. Treatments were designed to result in similar ADG and the trial lasted 62 days. A partial budget was used to compare costs and calculate cost of gain associated with each treatment. The CON, CSM, and DDG6 steers performed similarly but performance was decreased when dried distillers grains was fed 3 d/week (Table 18). Steers in the DDG3 treatment were offered

Table 17. Weight, body condition score (BCS), and conception rates of heifers in two systems: CON, which were fed hay with supplement, and TRT, which used increasing amounts of corn gluten feed along with grazed winter forage

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.

twice the amount offered to DDG6 on alternate supplementation days however DDG3 fed steers only consumed the daily equivalent of 3.9 lb/steer (DM) supplement over the course of the experiment. These results may be related to the fat content of DDGS because the reduction in gain is not completely accounted for by incomplete consumption of the supplement. This conclusion is supported by the results of Loy et al. (2004). These results verify previous research which has shown dried distillers grains has about 125% the energy of corn in forage based diets (Loy et al., 2003) since the DDGS calves were supplemented with 70% as much dry matter as CSM calves to provide equivalent energy intake. Cost of gain was greatest for CON treated steers primarily because of costs associated with feeding hay. Total costs were least but gain was also least for DDG3 steers making their cost of gain greatest among steers grazing range. Feeding dried distillers grains 6 days per week resulted in the lowest cost of gain.

A two-year study (Martin et al., 2007) evaluated DDGS compared to a control supplement that provided similar CP, energy, lipid, and fatty acids. The protein degradability of the supplements differed such that UIP exceeded requirements for heifers consuming the DDGS supplement. The heifers were program fed to gain 1.5 lb/day and reach 60% of mature weight at the time of breeding. Heifer

Table 18. Weight, average daily gain and cost of feeding steers a corn/soybean based supplement in a dry lot (CON) or while grazing native winter range (CSM) and feeding dried distillers grains while grazing range either 6 (DDG6) or 3 (DDG3) days per week

	Treatment					
Item	CON	CSM	DDG6	DDG3	SE[a]	P-value
Initial BW, lbs	468	468	470	470	1	0.98
Final BW, lbs	585[b]	594[b]	581[b]	560[c]	1	0.004
ADG, lbs/day	2.0[b]	2.0[b]	1.8[b]	1.4[c]	0.1	0.004
Supplement cost, $/hd	19.71	24.10	15.57	14.78		
Hay cost, $/hd	20.27	-	-	-		
Range cost, $/hd	-	8.60	11.11	11.38		
Total cost, $/hd	39.98	32.70	26.68	26.16		
Cost of gain, $/cwt	32.90	25.98	23.78	29.30		

[a]Standard error of the mean, n = 16.

pubertal development and overall pregnancy rate were not affected by supplement type and averaged 89% for each treatment. However, Artifical Insemination (AI) conception rate and AI pregnancy rate were improved by feeding DDGS in the heifer development diet. The proportion of heifers detected in estrus that conceived to AI service was higher for the DDGS treatment than for the control treatment. These data indicate that utilizing DDGS as a protein and energy source in heifer developing diets to promote moderate gains gives highly acceptable pregnancy rates and may enhance AI conception and pregnancy rates.

Cornstalk grazing

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 may reduce winter cattle costs. Given that 3.5 lb DM/day WCGF will meet the protein and phosphorus needs of calves, and feeding above 6.0 lb/day 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/day to calves grazing corn residue. Gains increased quadratically with ADG ranging from 0.90 to 1.81 lb.

WDGS STORAGE

One problem that can be encountered is storage of wet feeds. WDGS has been successfully bagged if no pressure is applied to the bagger. Bags tend to settle because of the weight of the WDGS, resulting in low height and expanded width. Modified wet distillers grains (45% DM) and WCGF bag well, even with pressure.

Adams et al. (2007) conducted two experiments to determine methods to store WDGS (34% DM), because WDGS will not store in silo bags under pressure or pack into a bunker. The first study evaluated three forage sources, as well as DDGS or WCGF mixed with WDGS. The products were mixed in feed trucks and placed into 9-ft. diameter silo bags. The bagger was set at a constant pressure of 300 psi. The height of the silo bag was a determining factor of storability. Inclusion levels of the feedstuffs were adjusted to improve the bag shape. The recommended levels of feedstuffs for bagging with WDGS (DM basis) are 15% grass hay, 22.5% alfalfa hay, 12.5% wheat straw, 50% DDGS, or 60% WCGF. The corresponding as-is percentages for the feedstuffs are 6.3, 10.5, 5.1, 27.5, and 53.7% of the mix, respectively. The second experiment was conducted by mixing grass hay with WDGS and storing in a concrete bunker. Both 30 and 40% mixtures of grass hay with WDGS (DM basis) packed into the bunker. These values correspond to 14.0 and 20.1% of the as-is grass hay mix. In both experiments, the product was stored more than 45 days and the apparent quality did not change. Wet DGS can be stored in a silo bag or bunker silo when mixed with drier or bulkier feedstuffs. More information is available at http://beef.unl.edu.

Storage allows cattle feeders with smaller numbers of animals to use wet co-products and not have the products deteriorate with extended time between deliveries of fresh material from the plant. Wet co-products are often more available and less expensive in the summer. Storage allows for purchase of wet co-products in the summer and subsequent feeding in the winter.

The resulting stored (ensiled) mix of wheat straw and WDGS has been fed to stocker calves. The palatability of the straw (cornstalks as well) seems to have been enhanced by storage. The feeding value is at least equal to what would be expected from the mathematical blend of WDGS and wheat straw. Further, the resulting mix after storage can be fed on the ground in range and pasture situations where cubes (cake) are normally fed on the ground.

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-products 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. Dakota Bran Cake is a distillers co-product feed produced as primarily corn bran plus distillers solubles produced from a prefractionation 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. Bremer et al. (2005) evaluated Dakota Bran Cake in a finishing diet by comparing inclusion levels of 0, 15, 30, and 45% of diet DM. Results indicated improved final weight, ADG, DMI and F:G compared to feeding a blend of HMC and DRC, suggesting this specific feed has 100-108% of the feeding value of corn. Buckner et al. (2007c) compared dried Dakota Bran Cake to DDGS supplementation in growing calf diets. They fed each of the two products at 15 or 30% of the diet replacing a 70:30 blend of brome grass hay and alfalfa haylage (DM basis). Animal performance improved as the inclusion of the co-products increased. DDGS had improved performance compared to the dried Dakota Bran Cake at both inclusion levels. Dried Dakota Bran Cake had 84% the feeding value of DDGS with growing steers. Previous research has shown that DDGS has about 127% the feeding value of corn in forage based diets. Therefore, dried Dakota Bran Cake appears to have an energy value equal to 103% 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-products 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, CGF, or a combination of both co-products, offer many feeding options to producers when included in feedlot diets. These co-product feeds may effectively improve cattle performance and operation profitability. WDGS and WCGF have feeding values greater than DRC in beef finishing diets. Drying appears to reduce the feeding value of co-products. The ability to keep cattle on feed and acidosis control are likely responsible for the higher apparent feeding values and may be the primary advantages of using WDGS and WCGF in feedlot diets. Understanding and managing variations in fat and sulfur levels in DGS products may help optimize DGS inclusion in feedlot diets. It appears that WDGS feeds better with HMC and DRC than with steam flaked corn. With feedlot cattle, more intense corn processing may be optimal for diets containing WCGF. It appears that WCGF is a complementary feedstuff for diets containing WDGS, SFC, HMC, and DRC. The quality and quantity of 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. The high UIP value of the DGS and WCGF make them excellent protein sources for young, rapidly growing cattle and lactating cows. Alternate day (or three days/week) feeding appears to be feasible and DGS may have an advantage to grains, non-protein nitrogen sources, and more degradable protein sources in alternative day feeding systems. Innovative ways of storing wet products offer opportunities for smaller producers to capture the value of co-products feeds. It also appears that 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 their respective feeding values.

LITERATURE CITED

The following research articles were cited in this publication. The reader is encouraged to view individual citations for a more in-depth discussion of individual trial details. University of Nebraska Beef Cattle Reports discussing ethanol co-product feeds for cattle and other cow/calf, growing, feedlot, beef products, and new beef technology are available on the Web at http://beef.unl.edu.

- Adams, D., T. Klopfenstein, and G. Erickson. 2007. Evaluation of storage methods for wet distillers grains plus solubles with forages and byproducts in silo bags and bunker silos [abstract 833]. J. Anim. Sci. (in press).
- Benton, J., G. Erickson, T. Klopfenstein, K. Vander Pol, and M. Greenquist. 2007. Effect of roughage source and level with the inclusion of wet distillers grains on finishing cattle performance and economics. Nebraska Beef Rep. MP-90:29.
- Blanchard, P. H. 1992. Technology of corn wet milling and associated processes. Industrial Chemistry Library, Vol. 4. Elsevier, New York.
- Bremer, V.B., G.E. Erickson, T.J. Klopfenstein. 2007. UNL Meta-analysis on the effects of WDGS and Sweet Bran on feedlot cattle performance and carcass characteristics. Proceedings of Plains Nutrition Council Spring Conference AREC 07-20:88.
- Bremer, V. B, G.E. Erickson, T.J. Klopfenstein, M. L Gibson, K. J. Vander Pol, M.A. Greenquist. 2005. Feedlot performance of a new distillers byproduct (Dakota Bran) for finishing cattle [abstract 215]. J. Anim. Sci. 83:(Suppl. 1.)
- Buckner, C., G. Erickson, T. Klopfenstein, R. Stock, and K. Vander Pol. 2007a. Effect of feeding a by-product combination at two levels or by-product alone in feedlot diets. Nebraska Beef Rep. MP90:25-26.
- Buckner, C., T. Klopfenstein, G. Erickson, D. Mark, and V. Bremer. 2007b. Economic model for determining byproduct returns in finishing diets [abstract 24]. J. Anim. Sci. 85(Suppl. 2).
- Buckner, C. T. Klopfenstein, G. Erickson, K. Vander Pol, K. Karges, and M. Gibson. 2007c. Comparing a modified dry by-product to dry distillers grains with solubles in growing calf diets. Nebraska Beef Rep. MP90:15-16.
- Buckner, C., T. Mader, G. Erickson, S. Colgan, K. Karges, and M. Gibson. 2007d. Optimum levels of dry distillers grains with solubles for finishing beef steers. Nebraska Beef Rep. MP90:36-38.
- Cooper, R.J., C.T. Milton, T.J. Klopfenstein, T.L. Scott, C.B. Wilson, and R.A. Mass. 2002. Effect of corn processing on starch digestion and bacterial crude protein flow in finishing cattle. J. Anim. Sci. 80:797-804.
- Corrigan, M., G. Erickson, T. Klopfenstein, K. Vander Pol, M. Greenquist, M. Luebbe, K. Karges, and M. Gibson. 2007a. Effect of distillers grains composition and level on steers consuming high-quality forage. Nebraska Beef Rep. MP-90:17.
- Corrigan, M., G. Erickson, T. Klopfenstein, K. Vander Pol, M. Greenquist, and M. Luebbe. 2007b. Effect of corn processing and wet distillers grains inclusion level in finishing diets. Nebraska Beef Rep. MP-90:33.
- DeHaan, K., T. Klopfenstein, R. Stock, S. Abrams and R. Britton. 1982. Wet distillers byproducts for growing ruminants. Nebraska Beef Rep. MP-43:33.
- DeHaan, K., T. Klopfenstein, and R. Stock. 1983. Corn gluten feed-protein and energy source for ruminants. Neb. Beef Rep. MP-44:19.
- Fanning, K, T. Milton, T. Klopfenstein and M. Klemesrud. 1999. Corn and sorghum distillers grains for finishing cattle. Nebraska Beef Rep. MP-71A:32.
- Farlin, S.D. 1981. Wet distillers grains for finishing cattle. Amin. Nutr. Health. 36:35.
- Farran, T.B., G.E. Erickson, T.J. Klopfenstein, C.N. Macken, and R.U. Lindquist. 2004. Wet corn gluten feed and alfalfa levels in dry-rolled corn finishing diets. Nebraska Beef Rep. MP80-A:61-63.
- Firkins, J.L., L.L. Berger and G.C. Fahey, Jr. 1985. Evaluation of wet and dry distillers grains and wet and dry corn gluten feeds for ruminants. J. Anim. Sci. 60:847.
- Green, D., R. Stock, and T. Klopfenstein. 1987. Corn gluten feed – a review. Nebraska Beef Rep. MP52:16-18.
- Gustad, K., T. Klopfenstein, G. Erickson, J. MacDonald, K. Vander Pol, and M. Greenquist. 2006. Dried distillers grains supplementation to calves grazing corn residue. Nebraska Beef Rep. MP 88-A:36.

REFERENCES

- Ham, G.A., R.A. Stock, T.J. Klopfenstein, E.M. Larson, D.H. Shain, and R.P. Huffman. 1994. Wet corn distillers byproducts compared with dried corn distillers grains with solubles as a source of protein and energy for ruminants. J. Anim. Sci. 72:3246-3257.
- Ham, G. A., R. A. Stock, T. J. Klopfenstein, and R. P. Huffman. 1995. Determining the net energy value of wet and dry corn gluten feed in beef growing and finishing diets. J. Anim. Sci. 73:353–359.
- Herold, D., M. Klemesrud, T. Klopfenstein, T. Milton, and R. Stock. 1998. Solvent-extracted germ meal, corn bran and steep liquor blends for finishing steers. Nebraska Beef Rep. MP69-A:50-53.
- Holt, S. M., and R. H. Pritchard. 2004. Composition and nutritive value of corn co-products from dry milling ethanol plants. South Dakota State Beef Report.
- Huls, T. J., M. K. Luebbe, G. E. Erickson, and T. J. Klopfenstein. 2008. Effect of inclusion level of modified distillers grains plus solubles in finishing steers. Nebraska Beef Report (in press).
- Jordon, D.J., T. Klopfenstein, and T. Milton. 2001. Wet corn gluten feed supplementation of calves grazing corn residue. Nebraska Beef Rep. MP 76-A:41-43
- Kissinger, W., R. Massey, R. Koelsch, and G. Erickson. 2006. Economics of manure phosphorus distribution from beef feeding operations. Nebraska Beef Rep. MP88-A:98-102.
- Klopfenstein, T., L. Lomas, D. Blasi, D. Adams, W. Schacht, S. Morris, K. Gustad, M. Greenquist, R. Funston, J. MacDonald, and M Epp. 2007. Summary analysis of grazing yearling response to distillers grains. Nebraska Beef Rep. MP90:10-11.
- Krehbiel, C.R., R.A. Stock, D.W. Herold, D.H. Shain, G.A. Ham, and J.E. Carulla. 1995. Feeding wet corn gluten feed to reduce subacute acidosis in cattle. J. Anim. Sci. 73:2931-2939.
- Larson, E.M., R.A. Stock, T.J. Klopfenstein, M.H. Sindt and R.P. Huffman. 1993. Feeding value of wet distillers byproducts from finishing ruminants. J. Anim. Sci. 71:2228.
- Loy, T. W., T. J. Klopfenstein, G. E. Erickson, and C. N. Macken. 2003. Value of dry distillers grains in high-fiber diets and effect of supplementation frequency. Nebraska Beef Cattle Report MP 80-A:8.
- Loy, T., D. Adams, T. Klopfenstein, J. Musgrave, and B. Teichert. 2004. A system for wintering spring-calving bred heifers without feeding hay. Nebraska Beef Rep. MP 80-A:7-9.
- Loza, P., K. Vander Pol, G. Erickson, T. Klopfenstein, and R. Stock. 2005. Effect of feeding a by-product combination consisting of wet distillers grains and wet corn gluten feed to feedlot cattle. Nebraska Beef Rep. MP 83-A:45-46.
- Loza, P.L., K. J. Vander Pol, G. E. Erickson, R. A. Stock, and T. J. Klopfenstein. 2004. Corn milling byproducts and alfalfa levels in cattle finishing diets. J. Anim. Sci. 82 (Suppl. 1):158.
- Loza, P., K. Vander Pol, M. Greenquist, G. Erickson, T. Klopfenstein, R. Stock. 2007. Effects of different inclusion levels of wet distiller grains in feedlot diets containing wet corn gluten feed. Nebraska Beef Rep. MP90:27-28.
- Luebbe, M., G. Erickson, T. Klopfenstein, and M. Greenquist. 2007. Effect of wet distillers grains level on feedlot cattle performance and nutrient mass balance. Proceedings of Plains Nutrition Council Spring Conference AREC 07-20:98.
- Macken, C., G. Erickson, T. Klopfenstein, and R. Stock. 2006. Effects of corn processing method and crude protein level with the inclusion of wet corn gluten feed on finishing steer performance. Prof. Anim. Scient. 22(1):14-22.
- Martin, J., A. Cupp, R. Rasby, K. Moline, J. Bergman. M. Dragastin, and R. Funston. 2007. Utilization of dried distillers grains for developing beef heifers. Nebraska Beef Rep. MP90:5.
- NRC. 1996. Nutrient Requirements of Beef Cattle (7th Ed.). National Academy Press, Washington, DC.
- Oliveros, B., F. Goedeken, E. Hawkins, and T. Klopfenstein. 1987. Dry or wet bran or gluten feed for ruminants. Neb. Beef Rep. MP 52:14.
- Owens, F.N., M.A. Hinds, and D.W. Rice. 2002. Methods for calculating diet energy values from feedlot performance of cattle. J Anim Sci. 80(Suppl. 1):273.

- Owens, F.N., D.S. Secrist, W.J. Hill, and D.R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: a review. J Anim Sci. 75:868-879.
- Parsons, C.H., M.L. Galyean, G.A. Nunnery, P.D. Defoor, and G.B. Salyer. 2001. Effects of Sweet Bran brand corn gluten feed and roughage level on performance and carcass characteristics of finishing beef heifers. Burnett Center Internet Progress Report No. 9 Available at: http://www.asft.ttu.edu/burnett_center/progress_reports/bc9.pdf.
- Richards, C., R. Stock , T. Klopfenstein, and D. Shain. 1995. Effect of wet corn gluten feed and supplemental protein on calf finishing performance. Nebraska Beef Rep. MP62-A:26-28.
- Scott, T. L., C. T. Milton, G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2003. Corn processing method in finishing diets containing wet corn gluten feed. J. Anim. Sci. 81:3182-3190.
- Scott, T., T. Klopfenstein, R. Stock, and M. Klemesrud. 1997. Evaluation of corn bran and corn steep liquor for finishing steers. Neb. Beef Rep. MP 67-A:72-74.
- Sindt, J.J, J.S. Drouillard, E.C. Titgemeyer, S.P. Montgomery, C.M. Coetzer, T.B. Farran, J.N. Pike, J.J. Higgins, and R.T. Ethington. 2003. Wet corn gluten feed and alfalfa hay combinations in steam-flaked corn finishing cattle diets. J Anim Sci. 81:3121-3129.
- Stalker, L.A., T.J. Klopfenstein, D.C. Adams, and G.E. Erickson. 2004. Urea inclusion in forage based diets containing dried distillers grains. Neb. Beef Rep. MP 80-A:20-21
- Stalker, L.A., D.C. Adams, and T.J. Klopfenstein. 2006a. A system for wintering beef heifers using dried distillers grain. Neb. Beef Rep. MP 88-A:13.
- Stalker, L.A., D.C. Adams, and T.J. Klopfenstein. 2006b. Influence of dried distillers grains supplementation frequency on forage digestibility and growth performance. Neb. Beef Rep. MP 88-A:33-35.
- Stock, R. A., J. M. Lewis, T. J. Klopfenstein, and C. T. Milton. 1999. Review of new information on the use of wet and dry milling feed by-products in feedlot diets. Proc. Am. Soc. Anim. Sci. Available at: http://www.asas.org/jas/symposia/proceedings/0924.pdf.
- Stock, R.A. and R.A. Britton. 1993. Acidosis in Feedlot Cattle. In: Scientific Update on Rumensin/Tylan for the Professional Feedlot Consultant. Elanco Animal Health, Indianapolis, IN. p A_1.
- Stock, R., M. Sind, R. Cleale, and R. Britton. 1991. High-moisture corn utilization in finishing cattle. J. Anim. Sci. 69:1645-1656.
- Trenkle, A. 1997a. Evaluation of wet distillers grains in finishing diets for yearling steers. Beef Research Report-Iowa State Univ. ASRI 450.
- Trenkle, A. 1997b. Substituting wet distillers grains or condensed solubles for corn grain in finishing diets for yearling heifers. Beef Research Report - Iowa State Univ. ASRI 451.
- Vander Pol, K. J. G. Erickson, T. Klopfenstein, and C. Macken. 2004. Effect of wet and dry distillers grains plus solubles and supplemental fat level on performance of yearling finishing cattle. Nebraska Beef Rep. MP-80A:45.
- Vander Pol, K. J. G. Erickson, T. Klopfenstein, and M. Greenquist. 2005a. Effect of level of wet distillers grains on feedlot performance of finishing cattle and energy value relative to corn [abstract 103]. J. Anim. Sci. 83(Suppl. 2):55.
- Vander Pol, K. J., G. E. Erickson, M. A. Greenquist, and T. J. Klopfenstein. 2006. Effect of Corn Processing in Finishing Diets Containing Wet Distillers Grains on Feedlot Performance and Carcass Characteristics of Finishing Steers. Nebraska Beef Rep. MP88-A:48.
- Vander Pol. K., G. Erickson, and T. Klopfenstein. 2005b. Degradable intake protein in finishing diets containing dried distillers grains. Nebraska Beef Rep. MP83-A:42-44.

For more information on the feeding of corn milling co-products to beef cattle and information contained in this manual, contact:
Dr. Galen Erickson ■ University of Nebraska–Lincoln ■ Department of Animal Science
Room C220 ■ Lincoln, NE 68583-0908 ■ 402-472-6402
Visit the UNL Beef website at http://beef.unl.edu

NEBRASKA CORN BOARD

www.nebraskacorn.org

IANR