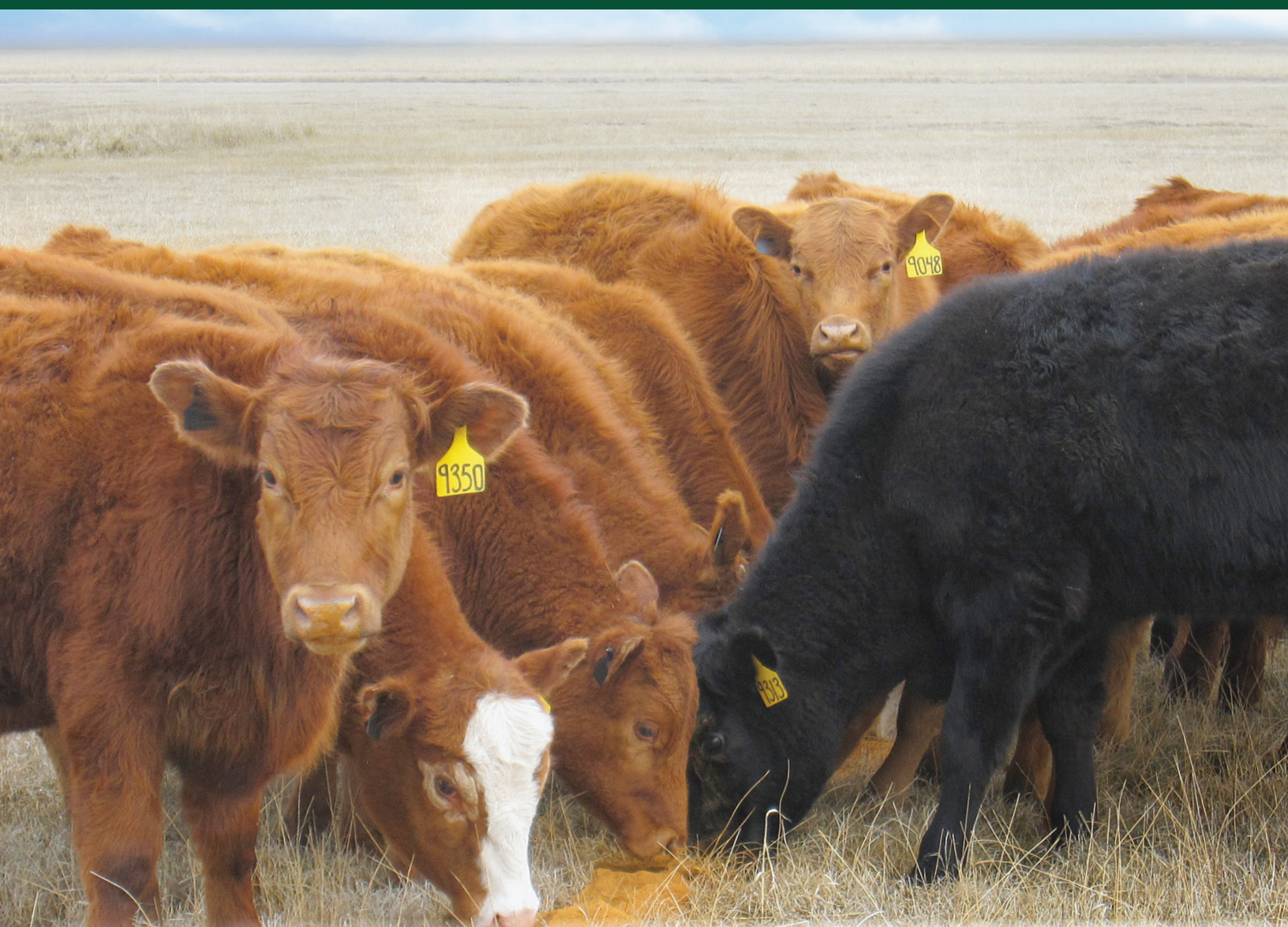


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Feeding Corn Milling Co-Products to Forage Fed Cattle



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Feeding Corn Milling Co-Products to Forage Fed Cattle

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INTRODUCTION

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 milling co-products are excellent sources of both protein and phosphorus and fit nicely into winter supplementation programs. Corn milling co-products are also an excellent source of energy and are particularly well suited to forage based diets.

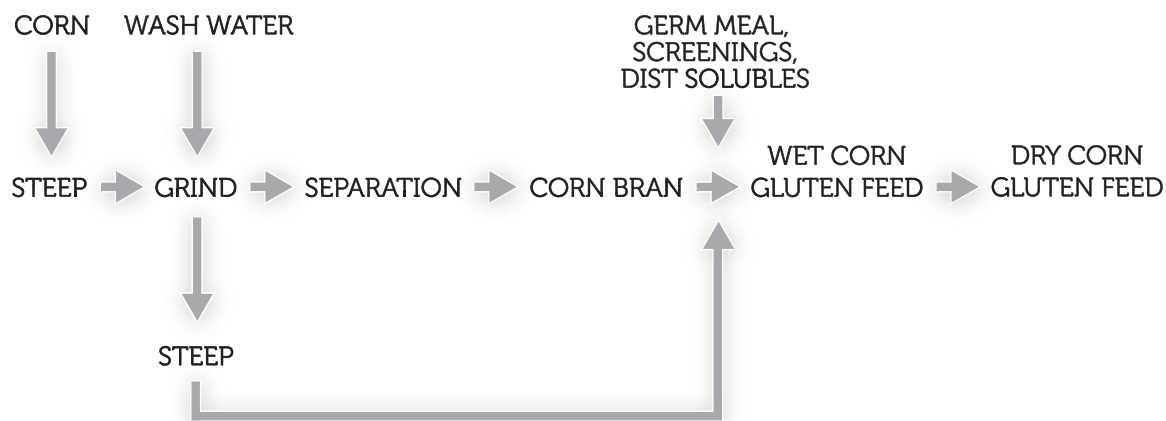
Two primary types of milling processes currently exist, resulting in quite different feed products. The dry milling process produces distillers grains plus solubles (DGS), and the wet milling process produces corn gluten feed (CGF). These feeds can be marketed as wet feeds or they can be dried and marketed as either dry corn gluten feed (DCGF) or dry distillers grains (DDG) with or without solubles. For the purposes of this publication, 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 WDGS is also expected. Therefore, these feeds may be very attractive for beef producers to use as feed sources. This publication will briefly review the milling process, then discuss nutrient content and feeding value, followed by feeding strategies. Finally, storage methods will be outlined.

MILLING PROCESSES

Wet Milling

Wet milling is a process that requires the use of high quality (U.S. No. 2 or better) corn that separates the corn kernel into different fractions to produce numerous products, some of which are 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 to steep the corn in that is initially brought into the process. 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 (high in 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, please refer to Blanchard (1992).

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



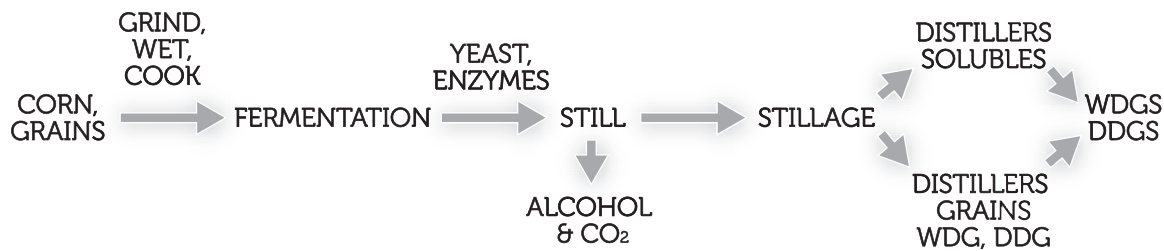
The actual composition of WCGF can vary depending on plant capabilities. Steep, a combination of steep liquor and distillers solubles, contains more energy (136% the feeding value of corn) and protein than corn bran or germ meal (Scott et al., 1997). Therefore, plants that apply more steep to corn bran or germ meal will produce WCGF that is higher in crude protein (CP) and energy. For instance, Sweet Bran is a trademarked WCGF product that Cargill makes. This product contains more steep and germ meal than other WCGF, causing it to have a higher energy value (112% the feeding value of corn).

WCGF contains 16-23% CP, of which about 70% is degraded in the rumen (degradable intake protein, DIP) and 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 because they are different products. Corn gluten meal contains approximately 60% CP of which 40% is DIP and 60% is bypass protein (also known as undegradable intake protein, UIP).

Dry Milling

The dry milling ethanol process (**Figure 2**) is relatively simple. Corn (or another starch source such as milo) is ground, and then the starch is converted to ethanol and CO₂ (fermentation). Approximately one-third of the dry matter (DM) remains as a feed product following starch fermentation, assuming the starch source is approximately two-thirds starch as is the case with corn. As a result, all the nutrients are concentrated three-fold, because most grains contain approximately two-thirds starch. For example, if corn is 4% fat, the DGS will contain approximately 12% fat.

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



After the ethanol distillation step, the resulting product, referred to as stillage, is centrifuged. The purpose of the centrifuging step is to separate the distillers grains from the distillers solubles. These distillers solubles are evaporated and are partially dried. Typically, the distillers solubles are added back to the distillers grains, however, individual plants vary in the amount of solubles that are returned to the grains. The nutrient composition will vary depending on the relative ratios of distillers grains to distillers solubles and if the distillers grains are dried partially before the solubles are added. If all of the solubles are added back to the grains, DGS are approximately 80% distillers grains and 20% distillers solubles on a dry matter (DM) basis (Corrigan et al., 2007). Most distillers grains contain some solubles, but the amount varies from plant to plant. Solubles are a good source of protein, are high in fat, phosphorus (P), and sulfur (S) and low in fiber (Corrigan et al., 2007). Solubles contain 25% CP (60% DIP), 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 steep from the wet milling industry and distillers solubles from the dry milling industry in place of molasses for liquid supplements.

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 food industries. Because the resulting feed products from these two industries are quite different it is important to understand the differences in the milling processes.

NUTRIENT CONTENT

Composition

Due to production process differences, corn milling co-products can vary in nutrient composition from plant to plant. An overview of this variability in composition of co-products is presented in **Table 1**. 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) represented in the table 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	90.0	44.7	60.0	90.4	34.9	35.5	45-50	49.4(49.0) ^e
SD	0.88	0.89	0.05	1.7	3.6	1.4	NA	1.0(0.58) ^e
CP, % of DM	9.8	19.5	24.0	33.9	31.0	23.8	NA	35.1
SD	1.1	0.63	0.51	1.3	0.9	1.5	NA	1.1
UIP, % of CP	60.0	20.0	28.0	65.0	65.0	25.0	NA	35.0
P, % of DM	0.32	0.66	0.99	0.51	0.84	1.72	NA	1.92
SD	0.04	0.03	0.04	0.08	0.06	0.27	NA	0.11
TDN, %	90.0	90.0	94.5	101	112	112	NA	113
NEg, Mcal/lb	0.70	0.71	0.80	0.78	0.87	0.87	NA	0.88

^a DRC=dry rolled corn with NRC (1996) values, WCGF=wet corn gluten feed from two plants, DDGS=dried distillers grains + solubles, WDGS=wet distillers grains + solubles, CCDS=condensed corn distillers solubles (corn syrup), MWDGS=modified wet distillers grains + solubles, steep is steep liquor from wet milling plants

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

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

^d DM values represent variation from daily composites for a 60-day 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

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 is a result of two things: process development to minimize variation and the quality control culture of personnel operating the plants to minimize variation in feed products.

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., 2007). 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 grains 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 to the grains from 0 to 22%, the resulting DDGS changed from a golden yellow color to a brown color. However, the change in color was not related to total digestive tract protein digestibility because the protein was 97-98% digestible in all samples.

Table 2. Composition of dried distillers grains with solubles

	Solubles Level, % ^a				
	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

^a Solubles level calculated using % NDF of solubles (2.3%) and 0% solubles DDG

Samples (n = 1200) of WDGS and modified WDGS (MWDGS, partially dried, 42-50% DM) were collected for five consecutive days, across four different months, and within six dry milling plants and analyzed for DM, CP, fat, P, and S (Buckner et al., 2008). Variation in DM content within each plant was minimal (coefficient of variation, CV, less than 3%), but DM was different across plants. Therefore, producers should be aware of the DM for each DGS product produced, particularly when buying DGS from more than one plant. On average, DGS contained 31.0% CP, 11.9% fat, 0.84% P, and 0.77% S. Variation within days, across days, and within the same plants remained small for CP and P (CV less than 4%), but P varied slightly more across plants. Fat content variation was slightly more but remained relatively small (CV less than 5%) within plants and within days, but larger variation was observed among ethanol plants. Fat content varied from 10.9 to 13.0% by plant, likely due to varying amounts of distillers solubles the plants return to the grains. Therefore, producers should know the fat content from each plant and not be concerned with fat variation within a plant. Variation in S content was the largest for all nutrients tested as CV within days and across days (within the same ethanol plants) ranged from 3 to 13%. These data suggest S values should be routinely monitored because high S levels can lead to nutritional challenges.

A review of several published literature articles summarized nutrient variability for DGS (Benton et al., 2010). Average nutrient composition for DGS was 31.5% CP, 10.5% fat, 6% starch, 43.2% NDF, 0.51% P, and 0.57% S. Relatively low variation was observed for CP, NDF, P, and S with CV of 10.7, 10.5, 8.4, and 6.3%, respectively. Greater variation was observed for fat and starch with CV of 31.4 and 36.3%, respectively. This large variation in fat and starch makes some logical sense as this is a summary of many samples over many ethanol plants. Not every ethanol plant combines the same proportion of distillers solubles to distillers grains, nor do they use the same procedure for analyzing fat content. Ethanol plants are not likely going to distill the same amount of starch from corn for ethanol production.

Feeding value

Corn milling co-products are excellent sources of both protein and phosphorus and fit nicely into winter supplementation programs. Stocker calves, developing heifers, and cows may need energy supplementation in addition to supplemental protein and phosphorus. Corn milling co-products are also an excellent source of energy that are particularly well suited to forage based diets. It is advantageous that 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. Because the starch is removed during the milling process, co-products do not cause negative associative effects on fiber digestion. Sometimes the addition of starch to forage diets can cause a decrease in fiber digestion because of competition between starch and fiber fermenting bacteria. Instead of starch, corn co-products contain highly digestible fiber, which is not disruptive to digestion of the fiber in the forage.

Clearly, CGF 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. CGF 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 dry-rolled corn (DRC) for growing calves fed grass hay, wheat straw, and corn storklage. The CGF or corn replaced 40% of the forage (Oliveros et al., 1987). The supplements nearly doubled gains and improved feed conversion (**Table 3**). Wet and dry 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.

Table 3. 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

In the case of DGS, a major source of the energy supplied to the animal is in the form of corn oil. Lipids contain 2.25 times more energy per unit weight than other nutrients. Because DGS is about 12% fat it is a concentrated source of energy. The nutrient content of DDGS can account for approximately 18% greater energy value than corn. However, the nutrient content alone cannot account for associative effects, positive or negative, that may exist and the actual energy value is much greater. A study by Loy et al. (2008) measured the total digestible nutrient (TDN) concentration of DDGS to be about 130% when fed at low levels but when fed at high levels it was only about 118% (**Table 4**). This decline may be due to the fat content of the DDGS and the subsequent effect on the ability of ruminal microorganisms to ferment fiber. Fat levels in the rumen greater than 5% have been shown to decrease fiber digestion through a variety of proposed mechanisms. In the Loy et al. (2008) study the fat of the high level of DDGS diet was about 5.2%.

Table 4. 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

		Low ^a	High ^a
ADG, lb/day	Corn	0.81 ± 0.06	1.57 ± 0.05
	DDGS	0.99 ± 0.05	1.89 ± 0.05
Feed conversion (DMI/ADG)	Corn	15.9 ± 0.5	9.8 ± 0.5
	DDGS	12.8 ± 0.5	8.0 ± 0.5

^a LOW = supplement fed at 0.21% BW, HIGH = supplement

Further studies have investigated the energy value of DGS. In a study by Nuttelman et al (2010) sixty crossbred steers were used to compare the energy value of WDGS to DRC in high forage diets at three levels. DRC was included at 22.0, 41.0, and 60.0% of the diet (DM), and WDGS was included at 15.0, 25.0, and 35.0% of the diet (DM). Diets were formulated to meet degradable intake protein and metabolizable protein (MP) requirements. Cattle consuming WDGS gained more than DRC cattle (**Table 5**). Average daily gain (ADG) increased with increasing levels of DRC and WDGS. The energy value of WDGS was calculated using the National Research Council model (1996). In this study, the energy value of WDGS was calculated to be 146, 149, and 142% the energy value of DRC.

Table 5. Effects of replacing DRC with WDGS fed at 0.81% BW in a forage based diet

	DRC	WDGS	SEM	P-value
Initial BW, lb	510	508	6	0.82
Ending BW, lb	696	711	7	0.13
DMI, lb/day	15.8	15.8	0.24	1
ADG, lb	2.21	2.42	0.05	< 0.01
F:G	7.14	6.54	0.003	< 0.01

Protein in forages is highly degraded in the rumen. In certain forage situations, light-weight growing cattle may need to be supplemented with undegraded intake protein to meet their MP requirements. Distillers grains (wet or dry) is an excellent source of undegraded intake protein. 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 MP. In both experiments, no response in performance was observed when urea was added to the diet (**Table 6**). 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.

Table 6. 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

Item	0	33	Diet			SEM	F-Test	
			67	100	133		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		

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. 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. 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.

An analysis of 14 separate grazing trials in which cattle were supplemented with DDGS was conducted by Griffin et al. (2009) to determine effects of supplementation on ADG and final bodyweight (BW) in pasture grazing situations. Additionally, pen studies were evaluated to determine the effects of DDGS supplementation on cattle intake, forage replacement, ADG, and final BW. In both the pasture and the pen studies, ADG and final BW increased quadratically with an increased level of DDGS supplementation (**Figure 3**). Feeding DDGS decreased forage intake quadratically; however, total intake for cattle supplemented DDGS increased quadratically with increased level of supplementation (**Figure 4**).

Figure 3. Effect of DDGS supplementation on ADG for growing cattle; pasture ADG (---), pen ADG (—)

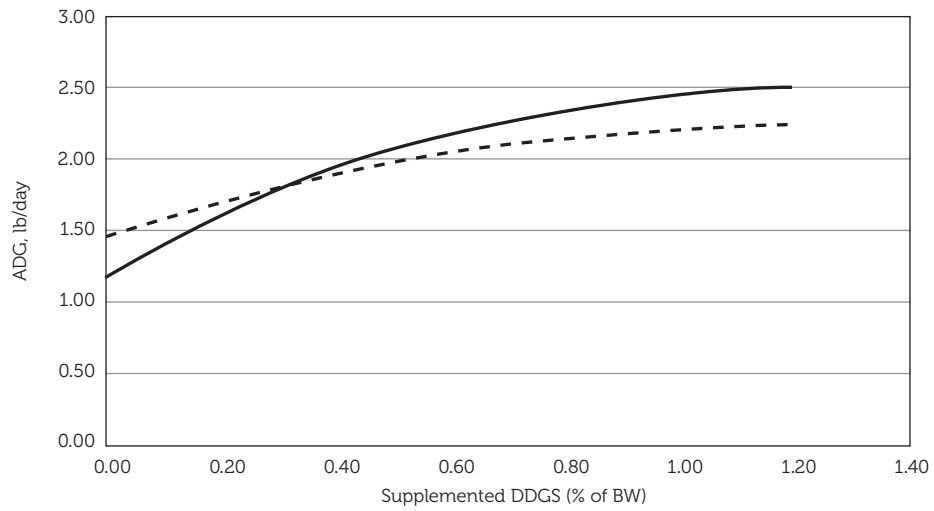
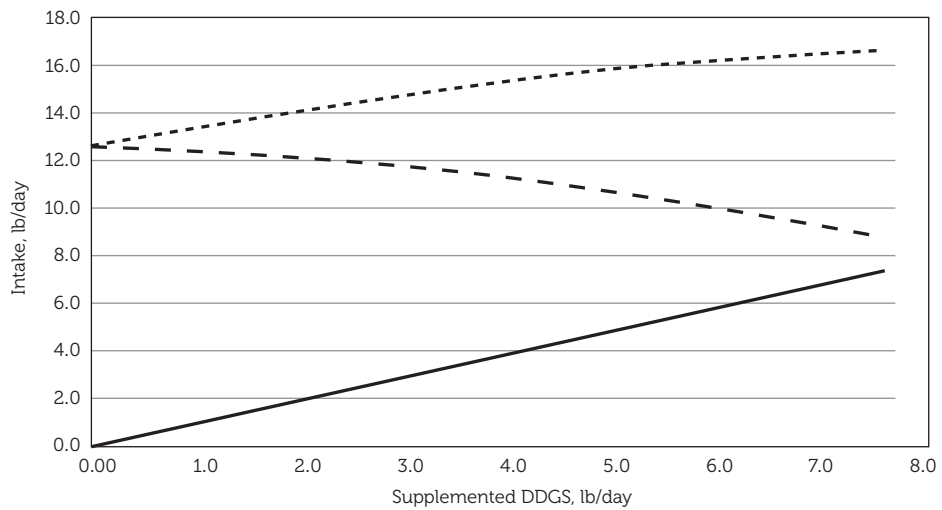


Figure 4. Effect of DDGS supplementation on intake for cattle fed in pen studies; DDG supplementation (—), forage intake (— —), total intake (---)



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., 2008). 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/day), but were not more efficient than those supplemented on alternate days. 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., 2007). Hay intake was higher for non-supplemented than for supplemented heifers (**Table 7**). No intake differences were observed 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.

Table 7. Treatment effects on intake, neutral detergent fiber disappearance, ruminal pH, and intake pattern

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

^a CON = no supplement; DRC-D = dry rolled corn supplement fed at 0.46% of BW daily; DRC-A = DRC at 0.92% of BW on alternate days; DDGS-D = dry distillers grains 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

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 8**; 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 score (BCS) 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.

Table 8. Weight, 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, % ^c	96.1	96.4

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

^c Percentage pregnant with second calf. P-value reflects chi square analysis

In a two year study, Stalker et al. (2006b) fed steers grass hay (6.6% CP) and 4.4 lb/day of a corn-soybean meal based supplement in a dry lot (CON), or fed 6.0 lb/day of the same corn/soybean meal based supplement six days/week (CSM), or the daily equivalent of 4.2 lb/day of a dried distillers grains based supplement either six days/week (DDG6) or three 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 three days/week (**Table 9**). Steers in the DDG3 treatment were offered 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., 2008) 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 six days per week resulted in the lowest cost of gain.

Table 9. Weight, ADG 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 six (DDG6) or three (DDG3) days per week

Item	Treatment				SE ^a	P-value
	CON	CSM	DDG6	DDG3		
Initial BW, lb	468	468	470	470	1	0.98
Final BW, lb	585 ^b	594 ^b	581 ^b	560 ^c	1	0.004
ADG, lb/day	2.0 ^b	2.0 ^b	1.8 ^b	1.4 ^c	0.1	0.004
Supplement cost, \$/head	19.71	24.10	15.57	14.78		
Hay cost, \$/head	20.27	-	-	-		
Range cost, \$/head	-	8.60	11.11	11.38		
Total cost, \$/head	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

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

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 pubertal development and overall pregnancy rate were not affected by supplement type and averaged 89% for each treatment. However, artificial 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.

Two experiments determined the effects of feeding WDGS, either on the ground or in a bunk, to cattle grazing native Sandhills winter range (Musgrave et al., 2010). In experiment 1, frequency of supplementation had no effect on cow BW or BCS. BCS and BW of cows fed in a bunk were improved compared to cows fed on the ground. In experiment 2, steers fed in a bunk had greater ADG than steers fed on the ground (**Table 10**). Feeding WDGS on the ground resulted in 13-20% waste and cost between 3.0 and 4.5 cents/day.

Table 10. Performance of steers fed WDGS on the ground or in a bunk

	Bunk	Ground	SEM	P-value
Initial weight (lb)	440	447	11	0.67
Final weight (lb)	481	475	11	0.71
ADG	0.36	0.44	0.07	0.04

Two studies were conducted over two years during the summer grazing season to determine the effect of grass intake when grazing cow/calf pairs were supplemented WDGS with low quality forage (Nuttelman et al., 2010). In 2007, a mixture of 45% WDGS and 55% grass hay was fed. In 2008, three blends of 50:50, 60:40, and 70:30 WDGS and wheat straw were fed. Supplemented cows and calves out gained non-supplemented groups in 2007 (**Table 11**). There were no differences in animal performance during 2008. Grazed forage intake was reduced by supplementing WDGS mixed with wheat straw without negatively affecting animal performance.

Table 11. Animal performance and grazed forage removal when WDGS mixed with wheat straw were fed to cattle grazing Sandhills upland range

Treatment	CON ¹	LOW ^{2,3}	MED ^{2,4}	HIGH ^{2,5}	SEM	P-value
Initial, lb						
Cow	880	882	893	893	20	0.63
Calf	276	280	267	267	15	0.53
ADG, lb/day						
Cow	-0.07	0.29	0.24	0.93	0.31	0.06
Calf	1.96	1.98	1.96	2.18	0.20	0.46
% Utilization	34.4 ^a	38.4 ^{ab}	44.3 ^b	46.0 ^b	0.3	0.01
DMI, lb/day						
Grazed intake ⁶	25.4	13.5	16.5	16.3	1.32	< 0.01
Supplement	—	12.8	12.6	12.4	0.2	< 0.01

^{a,b} Means with different superscripts differ (P-value < 0.05)

¹ Cattle grazed at the recommended stocking rate

² Cattle grazed at double the recommended stocking rate, and received 50% supplement of estimated daily intake

³ Cattle were supplemented with 70:30 wheat straw:WDGS mixture

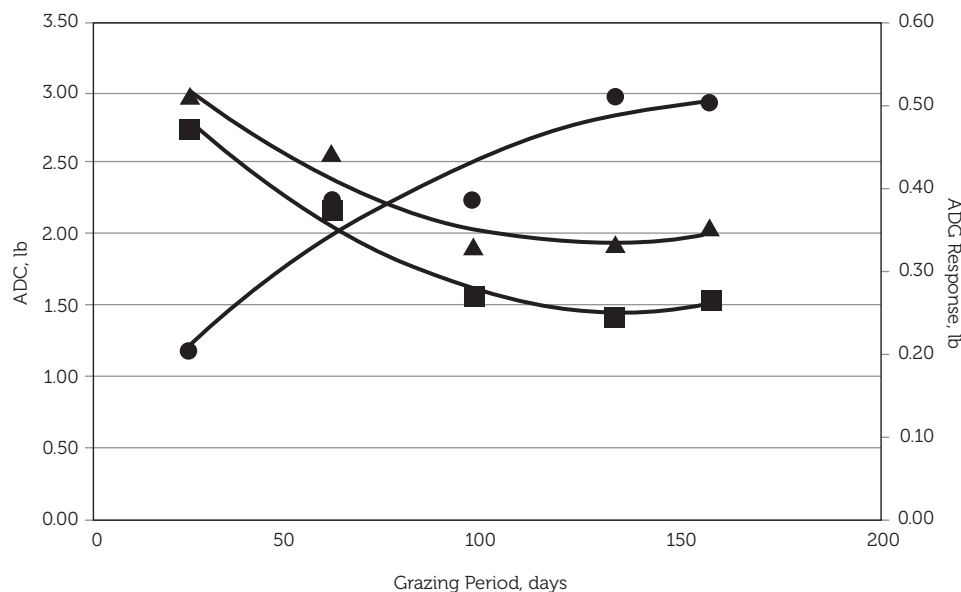
⁴ Cattle were supplemented with 60:40 wheat straw:WDGS mixture

⁵ Cattle were supplemented with 50:50 wheat straw:WDGS mixture

⁶ Calculated by dividing total amount of grazed forage disappearance by number of cow/calf pairs and number of grazing days

In a three-year study, DDGS were evaluated as a substitute for forage and nitrogen (N) fertilizer in yearling steers grazing smooth brome grass in eastern Nebraska (Greenquist et al., 2009). Stocking rate increased with N fertilization and DDGS, and ADG increased with DDGS. Total gain per acre increased by 53% with N fertilization and 105% with DDGS supplementation. N use efficiency was 139% greater per acre with DDGS supplementation compared to fertilizing with N alone. Feedlot ADG was similar among treatments with steers maintaining their BW advantage through the finishing phase (**Figure 5**).

Figure 5. Growth profile for steers grazing smooth brome grass and supplemented with dried distillers grains. The quadratic decrease in cumulative ADG for both supplemented (—▲—) and non supplemented (—■—) is expressed over the entire grazing period. The ADG response (—●—) of the supplemented cattle compared to non-supplemented increases as grazing days increase. ADG is inversely related to diet quality



Cornstalk grazing

Crop residues are a valuable feed resource for cattle producers. While grain remains in the field, the diet consumed is between 8.0 and 9.0 % CP and the TDN is as high as 70% (Wilson et al., 2004). This will exceed the protein and energy needs of a 1,200 lb cow in mid-gestation. Unless there is excessive wind damage or a disease problem, ear drop in corn fields is minimal. In addition, combines are efficient at harvesting much of the grain even if it is near the ground. Beef cows that graze cornstalk residue are selective grazers, selecting the grain first, followed by the husk and leaf, and finally the cob and the stalk. After the grain is removed from the field, the remaining residue will average 53 to 54% TDN and about 5.3% CP. For the 1,200 lb cow in mid-gestation to early late-gestation and average body condition, energy is adequate but the diet is deficient in protein. These cows appear to be approximately 0.38 lb deficient in CP.

Incremental levels of WCGF were fed to calves grazing corn residues. Based on statistical and economical analysis of the data collected, feeding WCGF (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, WCGF should be fed at 3.5-6.0 lb DM/day, producing gains from 1.28 to 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.

Experiments to determine supplementation strategies have been designed using corn residue and cows stocked at recommended rates. Spring-calving cows were supplemented to either meet a calculated protein deficiency and later in their stalk grazing period were supplemented to meet both a protein and energy deficiency were compared to a group of cows that were not supplemented while grazing cornstalk residue (Hall et al., 2008). There was no difference in weight gain between the supplemented and non-supplemented cows at the end of stalk grazing or before the start of the breeding season. Calf performance was not different nor was reproductive performance of the cows. BCS was different at the end of stalk grazing (5.8 versus 5.5) and in May prior to the start of the breeding season (5.6 versus 5.4) in favor of the supplemented cows. Although the differences in body condition are statistical, both groups of cows are in adequate condition and neither cow nor calf performance were affected. In another study, cows grazing cornstalk residue were either supplemented with 1 lb/head/day of a 28% protein supplement or not supplemented (Funston et al., 2009). Cow weight and body condition (5.3 versus 5.2) was less for cows that were not supplemented at calving. Weight was not different prebreeding and condition was 5.4 for supplemented and 5.2 for nonsupplemented cows. Calf performance was not different between the two groups. Pregnancy rate for both groups was greater than 95%. These data suggest beef cows, grazing corn residue are able to select a diet of sufficient quality to be in adequate body condition at calving if stocked at recommended rates.

Spring-calving heifers in mid-gestation grazing residue fields the first 25 days will likely meet both their protein and energy needs, and they should gain weight and body condition, especially if some corn is available. After the grain has been consumed, protein and energy supplementation appear to be needed. The remaining corn residue is between 53 and 54% TDN and CP during this time period will be about 5.3%. For the 1,020 lb heifer in mid-gestation and average body condition, energy and protein in the diet are deficient. These heifers are approximately 0.6-0.7 lb deficient in CP and 0.7-0.9 lb deficient in energy. Because distillers grains are excellent protein and energy and because there is a calculated deficiency in both protein and energy, it appears to be a good fit.

For lactating cows, such as fall-calving cows, grazing crop residue needs careful attention at least through the breeding season, because nutrient needs are high and nutrients supplied from the residue don't meet their needs. After the breeding season is completed, then management strategies to consider would include early weaning the calf and feeding it directly, supplementing the lactating cow to meet protein and energy deficiencies while grazing cornstalks, or feed some supplement to the lactating cow but not enough to meet the deficiency knowing that she will lose some weight and body condition. In an experiment comparing calving seasons, August calving cows were supplemented 1 lb/head/day of a 28% protein supplement comprised primarily of dried distillers grains while grazing cornstalk residue from October to April (Griffin et al., 2010). Rebreeding performance was 90%, but percentage of calves weaned per cow exposed was 85.7% for cows supplemented at this rate. Distillers grains purchased directly from the ethanol plant could be used as the supplement source in this management strategy.

An experiment was conducted using cornstalk residue and supplementation was used as part of the development program for replacement heifers (Larson et al., 2010). While grazing corn residue heifers were supplemented with 1-2 lb/head/day DM basis of a 28% CP cube. Yearling pregnancy rate varied between 84

and 92% and subsequent pregnancy rate as two-year-olds of these same females ranged between 77 and 100%. These data suggest when heifers were supplemented at the higher rate, reproductive performance was numerically greater. A producer could consider using DDGS as the supplement because it is a good protein (30% CP) and energy source.

Dry-lotting Beef Cows

Some advantages of dry-lotting cows include: less investment in land; small size cow/calf operators can increase their cow numbers without buying or renting additional land; diets can more closely meet the cow's nutrient needs as they change throughout the production cycle; drought is not a concern; it is easier to gather and treat animals that are sick or injured; it is easier to implement an artificial insemination program; calves are basically "bunk broke" as they are used to eating out of a bunk; and producer may have access to only cool-season grass pastures but no warm-season pastures

Some disadvantages of dry-lotting beef cows include: more labor and equipment are needed; cows need closer supervision; herd health program needs to be well designed and implemented; and if cows are naturally mated in a dry-lot, calves need access to a place that they can get away from the riding/breeding activities.

Dry-lotting beef cows may be an alternative to expensive grass, a way to expand the cow herd on a limited forage base, and a management alternative in a drought situation. It is important to check with the Department of Environmental Quality to determine if permits are needed for this type of confined animal feeding operation.

Pen size and lot space can be variable depending on soil type and drainage. A general recommendation is 500-800 square feet per pair. Plan on between 28 and 36 inches of bunk space per cow depending on cow weight. If the herd is a mix of young and old cows, it would be ideal to have separate pens for these groups. If separate pens are not possible, then hedge toward the higher number in regard to bunk space per cow. Diets for dry-lotted cows can contain a lot of forage and are bulky so deep feed bunks will help limit waste. In drought situations, forage may be expensive and used in limited amounts in the diet. A rule of thumb would be to have at least 0.5% of the cow's weight on a DM basis as forage to keep the rumen healthy. As an example, if the average weight of the cow herd that is being dry-lotted is 1,200 lb, then include at least 6 lb/head/day DM of forage in the diet. If the forage is 85% DM, then feed 7.0 lb/head/day (6 lb/head/day divided by 0.90 = 7.06). As the calf gets older it will come to the bunk and eat and diets need to be adjusted.

There are many ways to design diets for cow/calf pairs or nonlactating cows in a dry lot. Cheap or less expensive feeds are needed to make this a profitable enterprise. Baled corn stalk residue, Conservation Reserve Program hay, and straw can all work to stretch higher quality forages such as alfalfa. If cows are dry-lotted because of drought, forages are usually high priced. Depending on the price, corn may or may not fit into the diets for dry-lotted cows. An alternative to corn, especially in the summer, is corn co-products. Distillers grains are usually cheaper in the summer because it is a time when the number of cattle in the feedlot is low. Also, distillers grains (regular and modified) and gluten feed can be stored in bunkers or ag bags. Distillers grains are good sources of protein, energy, and phosphorus. Consider adding calcium to the diet because of the high phosphorus content of distillers grains. Mix the diet uniformly, pay attention to sulfur content, and make sure there is plenty of bunk space so all cows get their share.

Because of the high energy and protein content of distillers grains, it may not be necessary to feed cows to their capacity in a dry-lot situation. Dry-lotted, non-pregnant cows were fed either a control diet consisting of bromegrass hay, cornstalks, and alfalfa haylage or limit-fed either bunkered WDGS and corn stalks or bunkered distillers solubles (DS) and cornstalks (Kovarik et al., 2009). Cows fed the control diet were full-fed. Limit-fed cows were fed 17 lb/head/day DM basis (1.3% of their BW on a DM basis) of the bunkered material. Of the 17 lb/head/day of bunkered material fed, about 7 lb/head/day DM basis was either WDGS or distillers solubles. All treatment groups gained weight and the cows that were limit-fed either the bunkered WDGS or DS gained as much or more weight than the control group that was full-fed. Cows exhibited no signs of sulfur toxicity, but sulfur content should be monitored in limit-fed diets using WDGS and DS. Although fat level showed no negative effect on animal performance in this experiment, dietary fat should be closely monitored because of its possible negative effect on forage digestion. These data suggest non-lactating, non-pregnant mature beef cows can be maintained on a limit-fed diet of WDGS or DS. As a management consideration, limit-fed diets should contain some low quality forage to slow down rate of passage of the diet through the digestive tract, which will help cows adapt to being dry-lotted. These data have direct application if lactating pairs that are dry-lotted. Diets will need to be balanced for nutrients and account for calves consuming some of the diet.

STORAGE

Buying WDGS in the summer months can provide an opportunity for producers because these products historically are at their yearly economic low due to decreased demand. Producers can purchase large amounts of WDGS and store these until subsequent feeding in the winter. This is particularly helpful for small producers that cannot utilize much of this product within a short period of time. However, the main problem with storing these feeds is that they are very wet and bulky, which creates problems with the feed molding and difficulty in storing. 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. MWDGS and WCGF bag well, even with pressure.

Adams et al. (2008) 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.

Feeding Corn Milling Co-Products to Forage Fed Cattle Manual

More information is available at <http://beef.unl.edu>, including articles on methods and design, videos for examples, and an economic spreadsheet evaluating co-product storage. There has also been a manual, "Storage of Wet Corn Co-products" (Erickson et al., 2008) published that discusses wet co-product storage in more detail.

Spoilage amounts for a mix of 70% WDGS and 30% straw (DM basis) were evaluated in 55 gallon barrels with cover treatments including no cover, adding salt, covering with plastic, and covering with distillers solubles (Christensen et al., 2010). The greatest proportion of DM loss and spoilage came as a result of not covering the mixes (**Table 12**). When calculated to a 10 ft bunker, this equaled 4.9% spoilage. Intermediate amounts of spoilage resulted from covering with salt (2.0% spoilage) and very small amounts of spoilage (less than 1%) resulted from covering with plastic and distillers solubles. Therefore, plastic and distillers solubles serve as the best spoilage and DM loss preservation for storing wet co-products. However, DM loss of 25 to 50% of the solubles themselves are expected when used as a cover.

Table 12. Effect of storage covers for storing 70% WDGS with 30% ground corn stalks on DM loss and spoilage

	Control	Plastic	Salt	F-test
Barrel				
DM added, lb	115.4	115.13	114.8	0.95
DM spoilage, lb	20.2 ^a	3.1 ^b	19.8 ^a	< 0.01
DM loss, lb	17.6 ^a	0.0 ^c	4.2 ^b	< 0.01
10 ft. Bunker ¹				
% DM loss ²	3.4 ^a	0.0 ^c	0.82 ^b	< 0.01
% Spoilage ³	3.9 ^a	0.61 ^b	3.8 ^a	< 0.01
% DM spoilage and loss	7.4 ^a	0.57 ^c	4.7 ^b	< 0.01

¹ Losses and spoilage extrapolated to a bunker storage facility with 10 ft height assuming all losses are from the surface and therefore the same whether a 27-in barrel or 10-ft bunker

² % DM loss calculated based on the amount of loss as a percent of the total stored in a 10-ft tall bunker. The weight in a 10-ft bunker with 3 ft 2 in surface area is calculated from DM density added to barrels

³ % Spoilage calculated similar to method for calculating % DM loss but with amount of spoilage DM

^{a,b,c} Means with different superscripts differ (P < 0.05)

Understanding amounts of spoilage and DM loss for storing co-products is relatively unimportant unless nutrient composition of the spoiled fraction are known. Spoiled and non-spoiled fractions of the same 70% WDGS and 30% straw that was mentioned previously have been analyzed for changes in nutrient composition (Yelden et al., 2010). In general, the spoiled feed results in decreased fat and increased pH, NDF, CP, and ash compared to the unspoiled fractions. For the uncovered treatments, fat decreased from 10.6 to 4.9%, pH increased from 4.1 to 8.1, NDF increased from 42.2 to 52.9%, and ash increased from 8.1 to 12.0% for the unspoiled and spoiled fractions, respectively. These differences are reduced when plastic and/or solubles are used as a cover treatment. During storage, microbes utilize organic materials (particularly fat) for fermentation growth, hence the nutrient composition changes.

The feeding value of WDGS mixed with straw was evaluated by Buckner et al. (2010) and was compared to feeding fresh WDGS and straw mixed on the same day of feeding for growing cattle. Two mixtures included 30 and 45% WDGS (DM) with 70 and 55% straw, respectively. The bagged mixes had been stored in ag-bags for 45 days prior to trial initiation and were either applied with an inoculum that is proposed to aid in digestibility or not. To accurately determine the feeding value of the stored mixes, cattle consuming the stored mixes were pair-fed to the cattle that were fed ad libitum with the fresh mixes. Cattle that consumed greater WDGS had greater ADG and DMI, which calculated to improved F:G (**Table 13**). This suggests that increased levels of WDGS improves cattle performance in growing diets. Cattle fed the stored mixes had greater ADG and due to equal dry matter intake, had decreased F:G. This difference in F:G calculated out to a 24% improvement in feeding value due to storing of WDGS with straw.

Table 13. Steer performance for WDGS and straw mixes fed fresh or ensiled with or without inoculum

Performance	Fresh	Storage Type		P-value	Inter ¹
		Ensil-No Inoc	Ensil-W/Inoc		
Initial BW, lb	510	508	511	0.96	0.99
Ending BW, lb	585 ^a	597 ^b	604 ^b	0.43	0.71
DMI, lb/day	9.4	9.5	9.4	0.99	1.0
ADG, lb	0.89 ^a	1.07 ^b	1.11 ^b	0.02	0.16
F:G	10.7 ^a	9.0 ^b	8.6 ^b	< 0.01	0.10

¹ Interaction for mixture and type

^{a,b} Means within type of mix effect and the same row without a common superscript differ ($P \leq 0.05$)

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