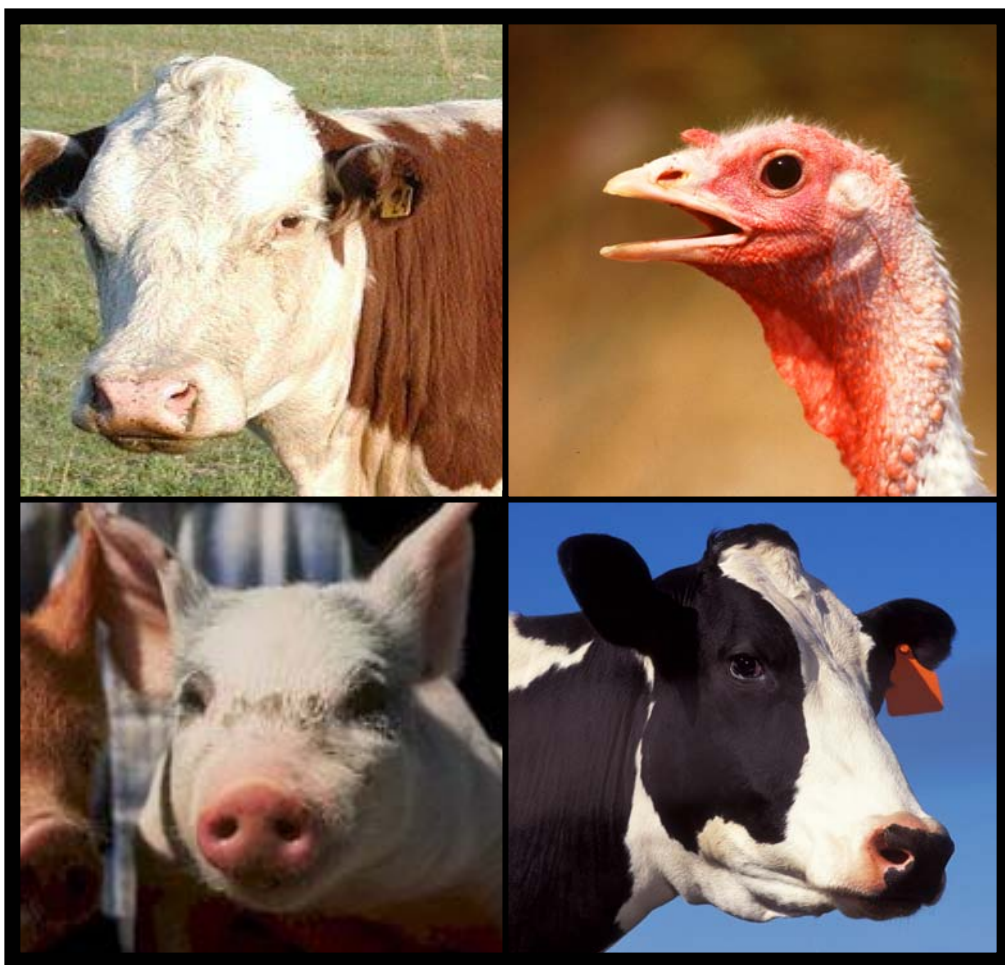


Distillers Grains Feeding Recommendations



**For Beef, Dairy,
Swine, and Poultry**

Compiled by the National Corn Growers Association



DISTILLERS GRAINS FEEDING RECOMMENDATIONS

The purpose of this document is to provide an introductory source of information on distillers grains feeding recommendations for beef, dairy, swine and poultry. This guide is by no means a comprehensive resource for distillers grains feed guidelines. Instead, it is meant to provide a small sample of recent feeding recommendations and associated research. The distillers grains inclusion levels recommended in each of the respective papers in this book may vary slightly and are based on independent feeding trial results. These recommendations are based on extensive research conducted by animal scientists and nutritionists from leading universities.

The National Corn Growers Association provides these feeding recommendations to assist producers in understanding generally-accepted feeding levels. However, all rations for specific herds should be formulated by a qualified nutritionist. Moreover, the NCGA has no control over the nutritional content of any specific product which may be selected for feeding. NCGA makes no warranties that these recommendations are suitable for any particular herd or for any particular animal. The NCGA disclaims any liability for itself or its members for any problems encountered in the use of these recommendations.

Background:

Continued rapid expansion in the ethanol industry will mean explosive growth in the supply of distillers grains. Ethanol production in the United States has grown dramatically in the past five years, and following passage of the Renewable Fuels Standard in 2005, this growth is expected to further accelerate.

The industry produced 3.41 billion gallons of ethanol in 2004, nearly two and a half times the 1.47 billion gallons produced in 1999. Approximately 4 billion gallons will be produced in 2005, according to industry estimates. During the 2004/05 crop year, 1.325 billion bushels of corn went to ethanol production, according to USDA. For the 2005/06 crop year, it is estimated that 1.5 billion bushels of corn will be used in ethanol, representing 14 percent of projected U.S. corn production.

A coproduct of dry-grind ethanol production is distillers grains, which are used by the livestock and poultry industries as a source of energy and/or protein in feed rations. The most common forms of distillers coproducts generated by dry-grind ethanol plants include: Distillers Wet Grains (DWG); Distillers Dried Grains (DDG); Distillers Wet Grains with Solubles (WDGS); Distillers Dried Grains with Solubles (DDGS); and Condensed Distillers Solubles (CDS).

Wet and dried distillers grains with solubles are the most common forms of distillers grains being marketed to livestock and poultry producers today. According to industry sources, approximately 60% of distillers grains are sold domestically and internationally in the form of DDG or DDGS. The remaining 40% are sold domestically as WDG or WDGS for use in ruminant feed markets, normally in close proximity to the plant producing the WDG and WDGS.

Ethanol plants produced approximately 7.3 million tons of distillers grains in 2004. Of that amount, more than 6.5 million tons (89%) were consumed domestically, while 786,603 tons (11%) were exported. Dry grind plants are projected to produce 8.89 million tons of distillers grains in the 2005/2006 crop year and more than 10 million tons in 2006/2007.

Assuming that the majority of future ethanol growth will be in dry grind production, it is estimated that plants will be generating approximately 16 million tons of distillers grains in 2012, or more than twice the amount produced in 2004. Accordingly, more distillers grains will be entering the feed market with each passing year.

Nutrient Profile

New generation distillers dried grains with solubles are an excellent source of protein and energy for livestock and poultry. Because the distillers grains from each plant are slightly different in composition and nutritional value, a standard nutrient profile does not exist. However, the profiles below are typical of most new generation distillers grains. The analyses below are representative of DDGS only. For typical analyses of DDG, WDG or WDGS, consult your nutritionist or local extension agency.

Table 1. Proximate analysis of distiller's dried grains with solubles originating from new ethanol plants in Minnesota and South Dakota compared to a sample from an older Midwestern ethanol plant (OMP) and published reference values^a

Sample origin	# of samples	DM (%)	CP (%)	Fat (%)	Fiber (%)	Ash (%)	NFE (%)	ADF (%)	NDF (%)	DE ^b (kcal/kg)	ME ^b (kcal/kg)
MN-SD											
Aberdeen	12	87.4 (1.7)	30.8 (10.2)	10.2 (10.5)	8.9 (11.1)	6.3 (14.8)	43.8 (8.8)	14.2 (8.0)	46.2 (10.0)	3909 (2.9)	3541 (3.2)
Bingham Lk	12	90.2 (1.0)	30.9 (7.6)	10.7 (6.1)	9.1 (6.6)	6.4 (15.1)	43.8 (8.4)	18.1 (7.5)	44.4 (5.0)	3883 (3.9)	3510 (4.0)
Benson	12	88.4 (1.0)	30.1 (2.7)	11.2 (5.0)	8.3 (5.6)	5.4 (11.4)	45.0 (2.9)	14.8 (51.8)	37.0 (19.7)	4020 (1.2)	3645 (1.2)
Claremont	12	89.1 (1.3)	31.4 (2.1)	11.4 (5.5)	9.2 (5.9)	5.6 (8.8)	42.4 (3.2)	13.8 (—) ^d	40.5 (4.9)	3982 (0.9)	3599 (0.9)
Luverne	12	87.2 (1.1)	29.8 (3.3)	11.7 (7.4)	8.3 (8.8)	5.8 (11.6)	44.9 (3.9)	16.0 (55.8)	36.8 (20.6)	4022 (2.1)	3654 (2.2)
Morris	12	90.0 (2.0)	30.7 (6.8)	10.2 (9.1)	8.8 (9.3)	5.5 (16.7)	44.8 (7.2)	15.8 (8.4)	44.5 (4.3)	3945 (1.5)	3568 (1.5)
Preston	11	88.7 (1.5)	28.7 (5.7)	11.4 (7.0)	8.4 (8.9)	6.7 (7.4)	44.9 (4.9)	16.3 (54.2)	36.7 (23.1)	3971 (1.5)	3610 (1.7)
Scotland	11	89.8 (1.4)	31.6 (4.9)	10.8 (4.4)	9.7 (5.2)	5.7 (16.3)	42.2 (5.3)	18.5 (10.1)	49.1 (3.1)	3932 (1.5)	3550 (1.8)
Winnebago	12	90.0 (0.6)	28.7 (4.1)	10.7 (5.9)	8.3 (5.7)	5.4 (12.5)	46.9 (2.8)	15.4 (11.2)	42.8 (3.7)	3995 (1.3)	3629 (1.3)
Winthrop	12	88.7 (0.8)	29.5 (3.3)	10.8 (5.5)	8.7 (4.3)	5.2 (7.6)	45.8 (3.8)	17.1 (6.6)	41.9 (2.4)	3989 (0.7)	3621 (0.7)
1997 – 99	118	88.9 (1.7)	30.2 (6.4)	10.9 (7.8)	8.8 (8.7)	5.8 (14.7)	44.5 (6.1)	16.2 (28.4)	42.1 (14.3)	3965 (2.2)	3592 (2.4)
OMP DDGS	4	88.3 (0.9)	28.1 (2.4)	8.2 (12.6)	7.1 (4.2)	6.3 (17.5)	50.3 (5.9)	16.7 (—) ^d	35.4 (—) ^d	3874 (0.2)	3521 (0.3)
Reference ^c											
NRC		93.0	29.8	9.0	4.8			17.5	37.2	3449	3038
HL		90.8	28.5								
FRI		93.0	29.0	8.6	9.1	4.8					3848

^a Nutrient values expressed on 100% dry matter basis. Coefficients of variation presented in parenthesis.

^b DE = [(CP * 4) + (NFE * 4) + (Fat * 9)] * 4.54; ME = DE * [(0.96 - (0.2 * CP))/100].

^c References are: Nutrient Requirements of Swine, 10th ed., 1998. (NRC), Heartland Lysine, Inc. Amino Acid Digestibility Tables, 1998. (HL), and Feedstuffs Reference Issue, Vol. 71 Num. 31, July 30, 1999. (FRI)

^d Only 1 sample analyzed

Table 2. Essential amino acid levels of distiller's dried grains with solubles originating from new ethanol plants in Minnesota and South Dakota compared to a sample from an older Midwestern ethanol plant (OMP) and published reference values^a

Sample origin	# of samples	Arg (%)	His (%)	Ile (%)	Leu (%)	Lys (%)	Met (%)	Phe (%)	Thr (%)	Trp (%)	Val (%)
MN-SD											
Aberdeen	12	1.31 (6.2)	0.82 (5.3)	1.14 (7.5)	3.69 (5.3)	1.02 (9.6)	0.65 (9.8)	1.53 (5.0)	1.21 (5.6)	0.27 (9.1)	1.56 (6.2)
Bingham Lk	12	1.23 (2.1)	0.78 (2.1)	1.10 (5.4)	3.51 (3.2)	0.91 (2.9)	0.53 (5.1)	1.47 (3.7)	1.12 (2.5)	0.25 (5.9)	1.46 (2.8)
Benson	12	1.15 (11.5)	0.75 (8.6)	1.17 (8.0)	3.62 (6.7)	0.74 (17.8)	0.53 (6.2)	1.50 (7.0)	1.17 (6.3)	0.24 (9.1)	1.55 (8.5)
Claremont	12	2.17 (4.2)	0.77 (4.3)	1.15 (6.0)	3.53 (3.1)	0.91 (10.1)	0.50 (2.5)	1.46 (2.8)	1.12 (3.4)	0.26 (5.8)	1.50 (3.7)
Luverne	12	1.25 (6.5)	0.78 (7.0)	1.07 (8.7)	3.42 (6.3)	0.94 (11.3)	0.58 (9.4)	1.42 (6.7)	1.14 (7.4)	0.25 (7.3)	1.47 (8.3)
Morris	12	1.15 (11.5)	0.73 (9.0)	1.15 (9.7)	3.47 (6.1)	0.79 (25.7)	0.49 (8.7)	1.42 (6.4)	1.12 (6.7)	0.24 (13.9)	1.49 (7.2)
Preston	11	1.18 (5.5)	0.76 (7.8)	1.05 (11.1)	3.43 (7.9)	0.85 (7.2)	0.55 (10.2)	1.43 (7.8)	1.14 (7.9)	0.24 (6.7)	1.43 (10.1)
Scotland	11	1.25 (7.8)	0.79 (7.2)	1.17 (8.2)	3.81 (7.5)	0.78 (11.2)	0.69 (6.4)	1.57 (7.3)	1.14 (6.0)	0.25 (6.9)	1.53 (7.5)
Winnebago	12	1.11 (9.9)	0.75 (7.6)	1.05 (8.3)	3.48 (5.6)	0.72 (19.7)	0.53 (3.9)	1.41 (6.7)	1.07 (6.4)	0.21 (8.4)	1.47 (7.1)
Winthrop	12	1.13 (8.7)	0.72 (8.0)	1.16 (5.6)	3.55 (3.3)	0.80 (16.4)	0.49 (5.4)	1.48 (3.2)	1.12 (3.1)	0.25 (8.9)	1.51 (6.1)
1997 - 99	118	1.20 (9.1)	0.76 (7.8)	1.12 (8.7)	3.55 (6.4)	0.85 (17.3)	0.55 (13.6)	1.47 (6.6)	1.13 (6.4)	0.25 (6.7)	1.50 (7.2)
OMP DDGS	4	0.92 (18.7)	0.61 (15.2)	1.00 (9.1)	2.97 (12.4)	0.53 (26.5)	0.50 (4.5)	1.27 (8.1)	0.98 (7.3)	0.19 (19.8)	1.39 (2.3)
Reference ^b											
NRC		1.22	0.74	1.11	2.76	0.67	0.54	1.44	1.01	0.27	1.40
HL		1.21	0.75	1.09	3.27	0.81	0.63	1.43	1.11	0.20	1.43
FRI		1.08	0.65	1.08	2.90	0.65	0.65	1.29	1.02	0.22	1.43

^a Nutrient values expressed on 100% dry matter basis. Coefficients of variation presented in parenthesis.

^b References are: Nutrient Requirements of Swine, 10th ed., 1998. (NRC)
Heartland Lysine, Inc. Amino Acid Digestibility Tables, 1998. (HL)
Feedstuffs Reference Issue, Vol. 71 Num. 31, July 30, 1999. (FRI)

Table 3. Mineral composition of distiller's dried grains with solubles originating from new ethanol plants in Minnesota and South Dakota compared to a sample from an older Midwestern ethanol plant (OMP) and published reference values^a

Sample origin	# of samples	Ca (%)	P (%)	K (%)	Mg (%)	S (%)	Na (%)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)
MN-SD											
Aberdeen	12	0.03 (44.9)	0.85 (15.3)	0.84 (14.3)	0.32 (14.0)	0.33 (21.8)	0.15 (28.8)	72.1 (39.6)	21.3 (57.5)	6.0 (24.8)	175.7 (60.9)
Bingham Lk	12	0.03 (13.9)	0.94 (6.9)	0.99 (9.5)	0.34 (7.5)	0.68 (23.8)	0.16 (96.2)	56.6 (8.0)	15.5 (9.1)	5.3 (8.8)	98.1 (13.1)
Benson	12	0.08 (17.4)	0.92 (7.1)	0.99 (5.3)	0.35 (6.0)	0.40 (16.4)	0.21 (19.4)	110.0 (31.2)	15.4 (14.2)	6.3 (12.0)	118.7 (5.9)
Claremont	12	0.07 (51.2)	0.95 (4.7)	1.06 (7.1)	0.34 (4.7)	0.38 (40.8)	0.20 (55.2)	130.0 (24.0)	15.3 (11.2)	5.4 (15.2)	144.7 (12.6)
Luverne	12	0.05 (36.6)	0.91 (3.1)	0.97 (7.6)	0.37 (5.2)	0.47 (29.4)	0.20 (24.4)	96.7 (24.2)	17.4 (27.9)	6.3 (15.4)	106.9 (25.2)
Morris	12	0.13 (33.6)	0.82 (12.2)	0.94 (10.9)	0.34 (13.3)	0.74 (21.9)	0.51 (44.8)	44.7 (11.7)	16.0 (15.7)	7.6 (18.9)	156.4 (31.3)
Preston	11	0.06 (50.6)	0.99 (8.2)	1.04 (7.6)	0.36 (6.4)	0.37 (37.9)	0.20 (49.8)	312.1 (18.9)	17.8 (25.5)	5.9 (14.6)	103.2 (16.5)
Scotland	11	0.03 (21.1)	0.70 (6.4)	0.69 (10.6)	0.25 (10.7)	0.46 (6.4)	0.12 (9.4)	60.2 (7.8)	10.7 (12.9)	6.1 (14.8)	90.5 (15.4)
Winnebago	12	0.06 (15.2)	0.89 (5.5)	0.84 (4.4)	0.33 (4.3)	0.54 (14.3)	0.17 (32.8)	52.2 (6.9)	13.8 (4.4)	4.7 (10.8)	75.3 (13.9)
Winthrop	12	0.07 (15.3)	0.94 (5.6)	1.03 (5.5)	0.35 (4.7)	0.36 (9.7)	0.46 (34.4)	55.1 (10.5)	14.7 (9.9)	5.3 (19.0)	124.3 (19.1)
1997 - 99	118	0.06 (57.2)	0.89 (11.7)	0.94 (14.0)	0.33 (12.1)	0.47 (37.1)	0.24 (70.5)	97.5 (80.4)	15.8 (32.7)	5.9 (20.4)	119.8 (41.1)
OMP DDGS	4	0.44 (34.7)	0.90 (7.5)	0.99 (8.7)	0.40 (3.3)	0.51 (43.5)	0.28 (65.2)	80.2 (30.5)	49.5 (66.6)	13.5 (63.6)	219.2 (52.5)
Reference ^b											
NRC		0.22	0.83	0.90	0.20	0.32	0.27	86.0	26.0	61.0	276.0
FRI		0.38	1.02	1.08	0.38	0.32	0.86	91.0	32.0	54.0	323.0

^a Nutrient values expressed on 100% dry matter basis. Coefficients of variation presented in parenthesis.

^b References are: Nutrient Requirements of Swine, 10th ed., 1998. (NRC)
Feedstuffs Reference Issue, Vol. 71 Num. 31, July 30, 1999. (FRI)

Source: Dr. Gerald Shurson, University of Minnesota

Dry-Grind Ethanol Production Coproduct Definitions

Source: Association of American Feed Control Officials (AAFCO) Feed Ingredient Definitions

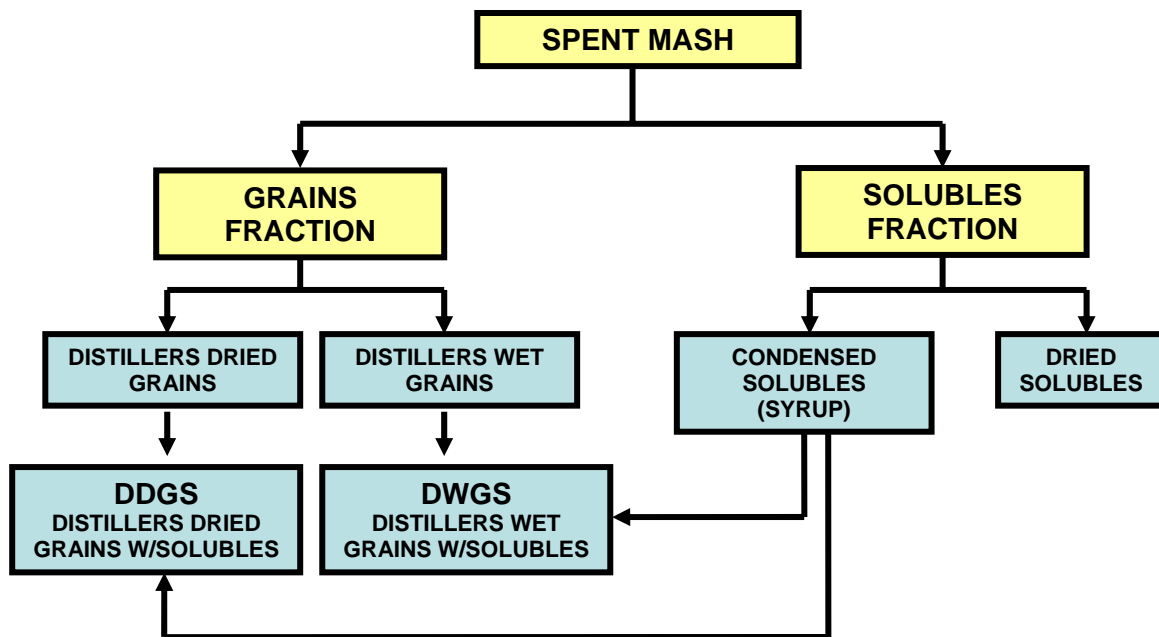
Corn Distillers Dried Grains (DDG) is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn by separating the resultant coarse grain fraction of the whole stillage and drying it. (27.5)

Corn Distillers Dried Grains with Solubles (DDGS) is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn by condensing and drying at least $\frac{3}{4}$ of the solids of the resultant whole stillage. (27.6)

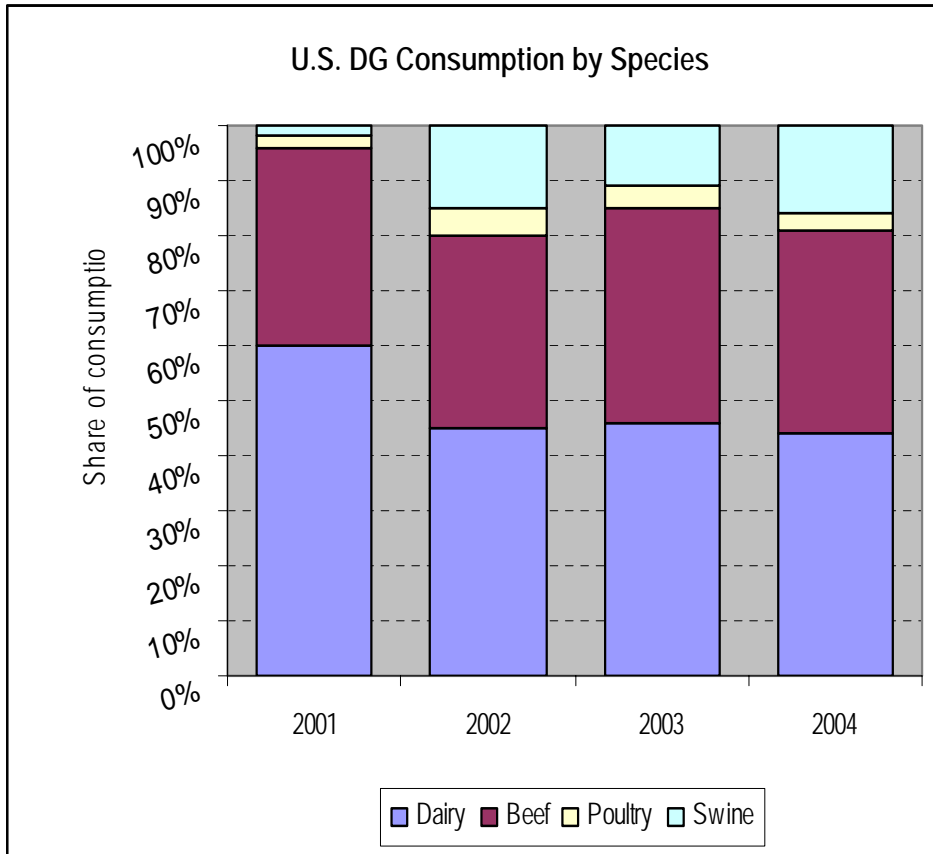
Corn Distillers Wet Grains (DWG) is the product obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn. (27.8)

Corn Condensed Distillers Solubles (CDS) is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn by condensing the thin stillage fraction to a semi-solid. (27.7)

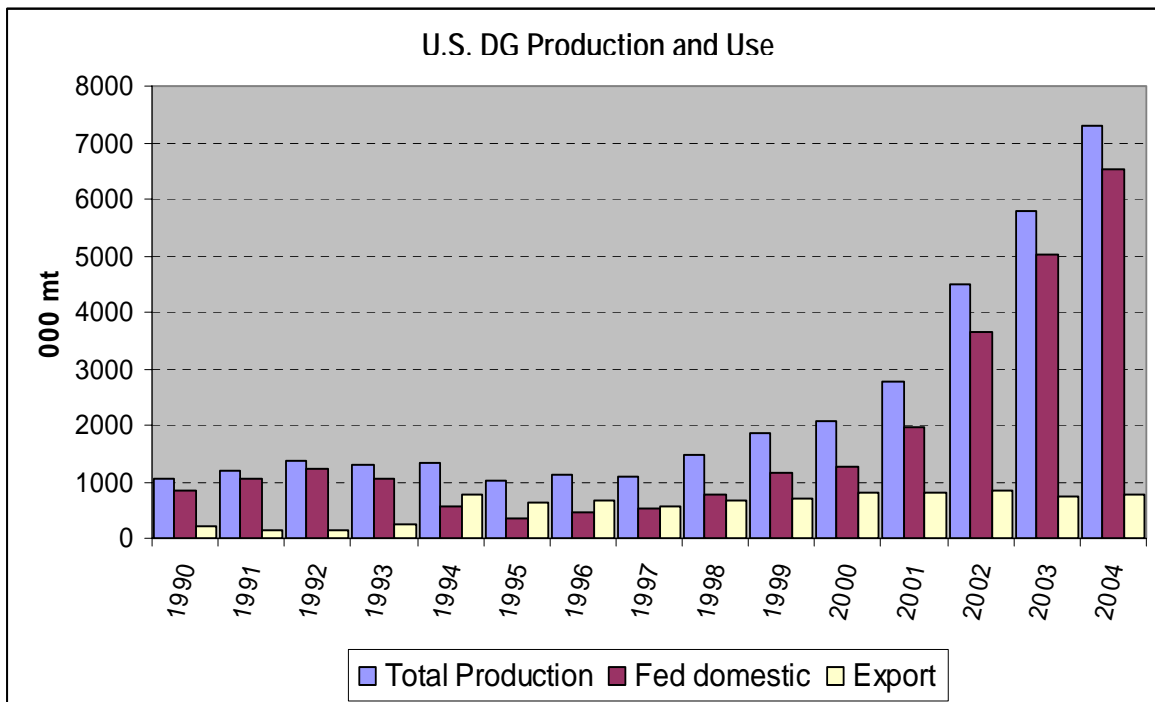
NOTE: Official AAFCO definitions do not exist for Distillers Wet Grains with Solubles (DWGS) and the variety of "modified" distillers grains products currently on the market.



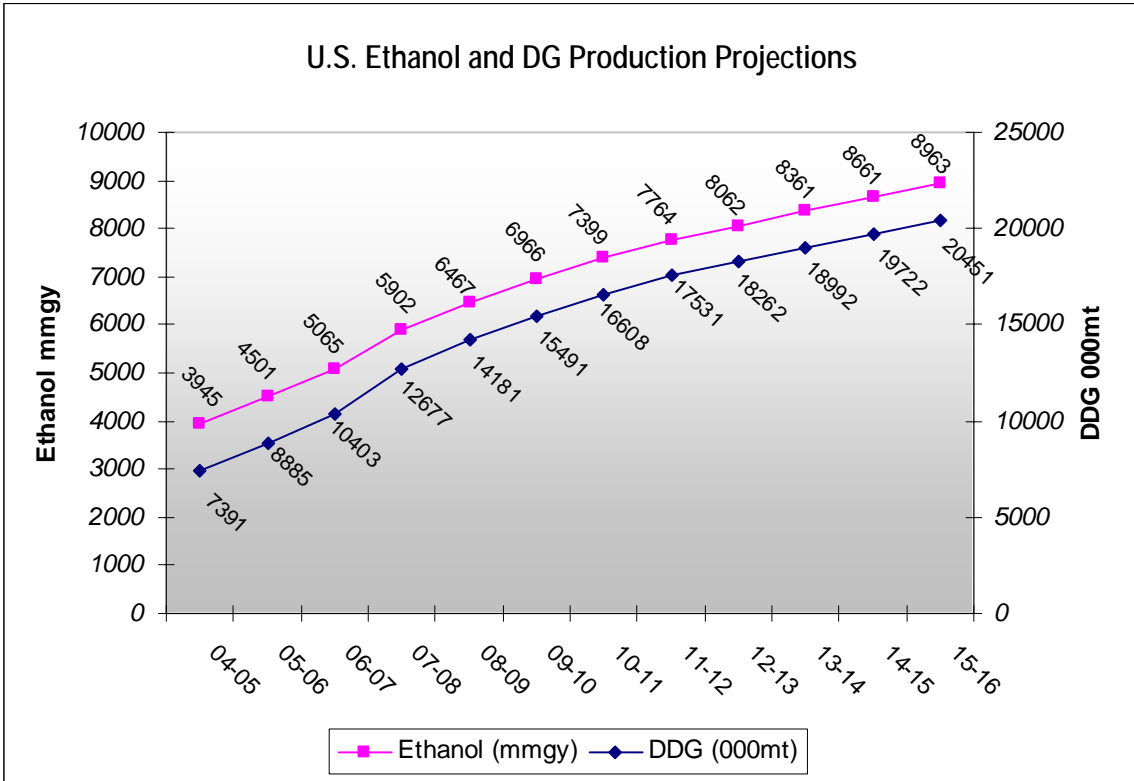
General Reference Data



Source: Commodity Specialists Company



Sources: ProExporter Network; Foreign Ag Service



Source: ProExporter Network

Additional Information

The following web-based resources provide extensive information on the use of distillers grains in livestock and poultry rations:

- University of Minnesota Distillers Grains Web Site: "The Value and Use of Distillers Dried Grains with Solubles (DDGS) in Livestock and Poultry Feeds," <http://www.ddgs.umn.edu/>
- Distillers Grains Technology Council, <http://www.distillersgrains.org/index.html>
- Iowa Department of Agriculture and Land Stewardship, Office of Renewable Fuels and Coproducts, <http://www.distillersgrains.com/>
- Distillers Feeds: Using Illinois By-Product Feeds in Livestock Feeding Programs, <http://ilift.trail.uiuc.edu/distillers/>
- Feedstuffs Magazine, <http://www.feedstuffs.com>

Additionally, most university extension services offer educational tools and services related to use of distillers grains. Many state corn grower associations also offer information on the use of distillers grains.

Acknowledgements

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- Dr. Sally Noll, University of Minnesota
- Dr. Terry Klopfenstein, University of Nebraska
- Dr. David Schingoethe, South Dakota State University
- Dr. Allen Trenkle, Iowa State University
- Brett Lumpkins, University of Georgia
- Greg Lardy, North Dakota State University
- Dr. Hans Stein, South Dakota State University
- John Goehl, Agri-Nutrition Services

The photographs used in this document are courtesy of USDA-ARS and Dr. Sally Noll, University of Minnesota, and are used by permission.

Solicitation

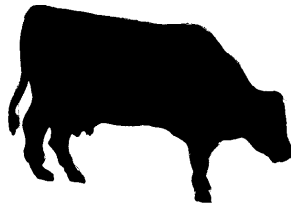
It is NCGA's intention to update this document periodically with new feeding recommendations as they become available. Distillers grains feeding recommendations may be submitted to NCGA at corninfo@ncga.com for consideration in future volumes. For more information, call (636) 733-9004.

Distillers Grains

Feeding Recommendations



DAIRY COWS
& DAIRY-BEEF



Summary of Distillers Grains Feeding Recommendations for Dairy Cows and Dairy-Beef

- “We recommend feeding a maximum of about 20% of total ration dry matter as distillers grains. This means 10 to 13 lbs. per cow daily of DDG or 30 or 40 lbs. per day of WDG for most lactating cows.”

— Dr. David Schingoethe, *Distillers Grains for Dairy Cattle*, South Dakota State University Extension Service Extension Extra, ExEx 4022, August 2004

- “Distillers grains are a palatable, high energy, fiber feed and a good source of UIP for use in feeding dairy cows. ...DDGS or DDG can comprise up to 26% of the dietary DM fed to dairy cows.”

— Dr. James G. Linn, University of Minnesota, and Dr. Larry Chase, Cornell University, *Using Distillers Grains in Dairy Cattle Rations*, Professional Dairy Conference Proceedings, 1996

- “Commonly, distillers grains and corn gluten feed are fed at 20% of the dietary dry matter, but recent research indicates that substantially more can in fact be fed, especially for CGF. Maximizing the use of these corn coproducts in ruminant diets will become increasingly important as more ethanol plants are built in the near future.”

— Dr. Terry Klopfenstein, University of Nebraska-Lincoln, *Uses of Corn Coproducts in Beef and Dairy Rations*, Minnesota Corn Growers Technical Symposium Proceedings, 2002

- “Recent research results from Iowa State University have shown that 10, 20 or 40% of the ration dry matter as dry distillers grains with solubles could be fed to growing Holstein steers from 425 to 700 lbs. without affecting feed intake or gain.”
- “Feeding 10, 20 or 40% dry distillers grains or 10 and 20% wet distillers grains did not affect carcass weight, marbling or yield grades.”

— Dr. Allen Trenkle, Iowa State University, *The Advantages of Using Corn Distillers Dried Grains with Solubles in Dairy Beef Diets (Iowa Corn Growers Association brochure)*, 2004

- “Dairy-beef steers should be fed DG at 12.5-37.5% of the diet for optimum performance, carcass composition and profit margins...”
- “Optimizing the use of distillers grains is becoming increasingly important as ethanol production increases. Dairy-beef production is a system that has potential to use large amounts of DG.”

— C.B. Rinker and L.L. Berger, *Optimizing the Use of Distiller Grain for Dairy-Beef Production*, University of Illinois, 2003

The National Corn Growers Association provides these feeding recommendations to assist producers in understanding generally-accepted feeding levels. However, all rations for specific herds should be formulated by a qualified nutritionist. Moreover, the NCGA has no control over the nutritional content of any specific product which may be selected for feeding. Producers should consult an appropriate nutritionist for specific recommendations. NCGA makes no warranties that these recommendations are suitable for any particular herd or for any particular animal. The NCGA disclaims any liability for itself or its members for any problems encountered in the use of these recommendations. By reviewing this material, producers agree to these limitations and waive any claims against NCGA for liability arising out of this material.

The Advantages of Using Corn Distillers Dried Grains with Solubles in Dairy Diets

- **An economical addition to dairy diets**
- **A very good protein and energy source for dairy rations**
- **The protein in new generation distillers grains:**
 - More than 30% of dry matter
 - A good source of ruminally undegradable (bypass) protein
 - A good quality protein although lysine is the first limiting amino acid
 - Production by dairy cows fed distillers grains as the protein supplement is as high as or higher than when fed soybean meal
- **The energy in new generation distillers grains:**
 - 10 to 15% higher than previously reported for distillers grains
 - More energy per pound than in corn
 - Replacing the starch in corn with the highly digestible fiber and fat in distillers grains may decrease digestive upsets
- **Recommend feeding a maximum of ~ 20% of ration dry matter as distillers grains**
 - Can usually formulate nutritionally balanced diets
 - At more than 20-25% of ration dry matter:
 - a) May decrease DM intake, especially if wet distillers grains
 - b) May decrease milk production when fed in high amounts
 - c) May feed excess protein and possibly excess phosphorus
- **Wet versus dried distillers grains:**
 - Nutrient content is the same for both
 - Storage and handling are considerations with wet distillers grains
- **New considerations with feeding wet distillers grains:**
 - Can store in silo bags for extended periods of time
 - Can blend with soyhulls, beet pulp, or corn silage
- **Considerations when selecting suppliers of distillers grains:**
 - Uniform nutrient content and quality
 - Watch for evidence of heat damage
 - “Modified” distillers grains may have certain fractions blended back into distillers grains. One needs to be aware of the nutrient content of such products so that total rations can be properly formulated using the modified distillers grains. Such products may actually be a higher value product to the producer, but one also wants a consistent product from one batch to the next.

For additional information on feeding distillers grains to dairy cattle contact:

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South Dakota State University
Brookings, SD 57007-0647
605-688-5483



Distillers Grains for Dairy Cattle

*D.J. Schingoethe, K.F. Kalscheur, and A.D. Garcia
Dairy Science Department*

Feeding distillers grains is nothing new; such products have been fed to cattle for more than a century. What is new, however, are the many ethanol plants now in the upper Midwest and the increased interest in feeding their co-product, distillers grains. This report is an overview of the nutritional value of distillers grains and gives some guidelines for feeding.

Nutrient composition

Distillers grains available today contain more protein and energy than those produced a number of years ago. For instance, most distillers grains available in the upper Midwest today contain 30% or more protein, more than the old “book values” of 23 to 26%. Today’s distillers grains are a good source of protein and energy for dairy rations (Table 1).

Protein content is similar for both distillers grains and distillers grains plus solubles (DDGS). Distillers grains are a good source of ruminally undegradable protein (RUP), with the RUP value being slightly less for wet (WDG) than for dried distillers grains (DDG). The protein in distillers grains is fairly good quality; lysine is its first limiting amino acid, a situation typical for all corn products.

As for energy, research at SDSU demonstrates that today’s distillers grains contain about 10% more energy (NEL = 1.0 Mcal/lb) than the old “book values” and that distillers grains contain more energy than corn. The product contains approximately 10% fat and a lot of readily digestible fiber.

Distillers grains—especially DDGS—is a good source of phosphorus, an advantage or disadvantage depending on phosphorus needs in the diets. Distillers solubles or syrup contain more than 1% phosphorus compared to less than 0.83% phosphorus in the dry material of DDG.

Most DDG have the solubles added, making it DDGS. WDG are usually—but not always—without solubles.

Production response when fed distillers grains

Research at SDSU and elsewhere shows that production, when distillers grains are in the ration, is the same as or greater than when soybean meal is the protein supplement.

Production did not always increase when distillers grains diets were supplemented with ruminally protected lysine and methionine.

Table 1. Composition of distillers grains

<i>Item</i>	<i>% of DM</i>
Crude protein	28-36
RUP ¹ , % of CP	47-63
NEL, Mcal/lb	1.0
Fat	8.2-11.7
Acid detergent fiber	19-24
Neutral detergent fiber	38-44
Calcium	0.10-0.15
Phosphorus	0.43-0.83

¹Ruminally undegradable protein

We obtained the same milk production from cows fed distillers grains as the supplemental protein as when they were fed a blend of soybean meal, fish meal, and distillers grains.

Condensed corn distillers solubles can also be fed directly to cattle even though the distillers solubles are often blended with distillers grains as DDGS. SDSU research demonstrated increased milk production when cows were fed 5% of the diet dry matter as condensed distillers solubles.

Thus, distillers grains are a good quality protein supplement which cannot be readily improved.

Wet vs. Dried Distillers Grains

The nutrient content of the dry matter is similar for both WDG and DDG. Thus, cost, availability, feed handling,

and other factors may determine whether you feed wet or dried products.

DDG can be stored for long periods of time. WDG can usually be stored only 5 to 7 days without experiencing some spoilage. Scientists at SDSU and elsewhere are working to extend the "shelf life" of WDG by ensiling, adding preservatives, or blending with other feeds such as soy hulls.

Because WDG are only 30 to 35% dry matter, economical hauling distances are less than for DDG. The high water content may also limit total dry matter intake and milk production, especially if ensiled forages are also fed. Aim for a total ration dry matter at 50% or higher.

At least one of the newer ethanol plants in South Dakota is offering a 50% dry matter distillers grains product by blending distillers solubles with DDG.

How Much Distillers Grains Can be Fed?

We recommend feeding a maximum of 20% of the total ration dry matter as distillers grains.

This means 10 to 13 lb per cow daily of DDG or 30 to 40 lb per day of WDG for most lactating cows. At this 20% level, you can usually formulate nutritionally balanced diets in a variety of forage programs and not limit feed intake.

In fact, distillers grains may be the only supplemental protein needed with a 50:50 blend of alfalfa and corn silage as the forages.

At 30% or more of ration dry matter as distillers grains, total dry matter intake may be decreased, especially if feeding WDG. At this level, the diet would likely contain excess protein if legumes are in the diet.

If the forages are mostly corn silage, you may be able to go up to 30% or more of the ration dry matter as DDG, but additional ruminally degradable protein and lysine may be needed and you will need to prevent excessive amounts of dietary phosphorus for good environmental nutrient management.

Beef cattle have been fed as much as 40% of the ration dry matter in Nebraska research, but dry matter intake decreased at more than 30% of ration dry matter, especially with WDG. Such diets, particularly the DDGS, supplied excessive amounts of protein and excessive phosphorus.

However, feedlot cattle experienced fewer cases of acidosis, laminitis, and liver abscesses when fed high distillers grains diets instead of high corn diets. This was likely because the ruminal fermentation of the fiber in distillers grains maintains a better rumen environment than does fermentation of the starch in corn and other grains. Distillers grains may also provide some protection against acidosis for dairy cows, although research data are not available to prove that.

Distillers Grains for Growing Heifers

Distillers grains can be used as a protein and energy source in diets for replacement heifers. Fifteen percent or less of the ration dry matter will often supply their protein needs.

WDG are not recommended for calves less than 6 months old, primarily because the high water content of the co-product may limit dry matter intake. Distillers grains are appropriate to feed to growing heifers when needed and priced right, but growing heifers will need smaller amounts than you would feed to lactating cows or feedlot steers.

Combining Distillers Grains with Other Byproducts

Distillers grains, either wet or dry, can be combined with other feedstuffs to increase their nutrient content.

SDSU research has shown that WDG can be preserved by ensiling alone or in combination with soy hulls. Soy hulls were combined with WDG at 0, 15, and 30% of the total weight and ensiled. The pH increased from 3.2 in WDG alone to 4.3 when soy hulls were blended with WDG in the 30% treatment. It has to be pointed out, however, that WDG has an intrinsically initial low pH (less than 3.7) due to the processing at the ethanol plant and not as a result of fermentation in the silo.

The 70:30 WDG:SH blend was further field tested in silo bags. Conservation was good when it was fed out daily. Acceptability of the new feed by dairy cattle was excellent.

The feasibility of pelleting DDG is also currently under study at SDSU. Pelleting offers the advantage of less feed wastage, as well as decreased transportation cost. Although straight DDG will not pellet due to high fat content, when soy hulls were included on a 50:50 mix by weight, the consistency of the pellets was adequate.

The analysis of the DDG:SH pellets on a dry matter basis was 21.6% crude protein, 7.7% crude fat, 29.2% acid detergent fiber, and 42.1% neutral detergent fiber.

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Distillers Grains for Dairy Cattle¹

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The feeding of distillers grains to dairy cattle is nothing new; such products have been fed cattle for more than a century. The research article by Loosli et al. (1952) referenced an 1895 Vermont Agricultural Experiment Station Bulletin that reported on the feeding of distillers grains to lactating cows. In many respects, one might say that responses to feeding distillers grains today should be similar to those older studies. That may be correct except for some differences in both distillers grains and cows today versus yesterday. The distillers grains are different today, primarily containing more protein and energy, and today's cows produce much more milk than was produced by their ancestors.

This presentation reports the results of recent studies in which distillers grains were fed to dairy cattle. While the emphasis of this presentation is on dried distillers grains, research conducted with both wet and dried products will be reviewed. Generally, one is referring to corn distillers grains (CDG) because that is what most of the studies in recent years have used; results with distillers grains from other grains would likely be similar. In most cases, the CDG used is dried distillers grains plus solubles (DDGS).

The composition of CDG today, especially products coming from the "new generation" ethanol plants in the Midwest, contain more protein and energy than older "book" values. For instance, the CDG, both wet and dried, that was used in our SDSU research contained 30 to 36% or more crude protein on a dry matter (DM) basis versus the 23% CP for CDG and 25% CP for DDGS values reported in the 1989 nutrient requirements of dairy cattle (NRC, 1989). The new dairy NRC (2001) lists 29.7% CP for DDGS, a number that is closer to reality. The net energy for lactation (NE_L) in today's CDG is about 10% higher (~ 1.03 Mcal/lb) than the 0.90 Mcal/lb reported in NRC (1989; 2001). Contents of fat (10% or more), neutral detergent fiber (~ 39%), and acid detergent fiber (~ 19%) are only slightly different from the NRC values. Improved efficiencies in fermenting more of the starch that was in the corn to ethanol is likely the reason for these observed changes in the composition of CDG.

Another nutritional consideration when feeding distillers grains or many other co-product feeds is the phosphorus content. Dried CDG contains approximately 0.43% P and DDGS contains approximately 0.83% P, reflecting the high P content (1.37%) of distillers solubles. This high P content can be an advantage because it can allow one to decrease the amount of supplemental P normally added to the diet. Or, it can be a disadvantage if nutrient management concerns about high P content of manure can't be avoided by decreasing amounts of P from other feed sources.

¹ Presented at Iowa Regional Distillers Grains Workshops, Calmar, Waverly, and Cherokee, IA, February 2004.

² Other researchers contributing to SDSU dairy distillers grains research include Drs. A.R. Hippen, K.F. Kalscheur and A.D. Garcia.

Protein in Corn Distillers Grains

Corn distillers grains is a good source of ruminally undegradable protein (RUP). The reported values of 55% of CP as RUP is probably an appropriate figure to use in most cases. Most reported values range from 47% to 57% RUP although we obtained somewhat higher values (Brouk et al., 1994). One often assumes that wet CDG has lower concentrations of RUP than does dried CDG, but the differences are slight. Firkins et al. (1984) reported 47% RUP for wet CDG and 54% RUP for the dried product, which probably represents a realistic difference in RUP for the wet versus the dried products. Most of the readily degradable proteins in corn have been degraded during the fermentation process, so the protein remaining in the CDG is going to be proportionately higher in RUP than in the original corn. However, if RUP values for dried CDG are quite high (e.g. > 80% of CP), it may be advisable to check for heat damaged, undigestible protein.

The quality of protein in CDG is fairly good. As with most corn products, lysine is the first limiting amino acid in CDG for lactating cows. More will be said about protein quality below in discussions about production responses to CDG.

Production Response When Fed Corn Distillers Grains

Table 1 summarizes milk production from several experiments in which cows were fed CDG. In experiments that compared CDG to soybean meal as the protein supplement, production was similar (Schingoethe et al., 1983; 1999) when fed wet CDG or higher (Nichols et al., 1998) when fed dried CDG than when fed soybean meal. With DDGS, production was similar to with soybean meal in a Nebraska study (Owen and Larson, 1991) and in a Florida study (Powers et al., 1995) in which the DDGS was dark and possibly heat damaged. When fed lighter colored DDGS from whiskey or from fuel-ethanol preparations, production was higher ($P < 0.05$) than when fed soybean meal (Powers et al., 1995). Some ethanol plants are striving to consistently produce improved quality DDGS products.

Several experiments evaluated the protein quality of CDG and how additional protein or amino acid supplementation can be used to improve productivity of lactating cows. In the trial by Nichols et al. (1998), production increased when cows were fed ruminally protected lysine and methionine (RPLM). Wisconsin researchers (L. Armentano et al., 1997, unpublished results) observed similar increases with lysine supplementation. This response was expected because the protein in diets based on corn products are typically limiting in lysine. The greater production with CDG-based diets than with soybean-based diets was impressive but not entirely expected based on previous research with other corn-based products such as corn gluten meal. A multi-university study (Polan et al., 1991) observed lower production when fed corn gluten meal in place of soybean meal, even when the corn gluten meal was supplemented with RPLM.

However, when one has obtained good results in an experiment, one shouldn't repeat it. The next step in our efforts to improve the quality of protein in diets of cows was to compare CDG as the only protein supplement to a blend of proteins that included CDG (Liu et al., 2000); both diets were fed with or without RPLM. Supplemental proteins fed in the BLEND diet were 25% from CDG, 25% from fish meal, and 50% from soybean meal. Theoretical evaluations of these diets (Schingoethe, 1996; O'Connor et al., 1993) indicated that the BLEND diet contained

a more desirable array of amino acids and should have supported greater production than the CDG diet. However, this time there was no additional production when the CDG diet was supplemented with RPLM. Also, production was not significantly higher when fed a blend of several high quality protein supplements instead of CDG as the only protein supplement.

The above studies illustrate that CDG is a good quality protein source and that it cannot be easily improved upon. Corn distillers grains can be easily used as the only source of supplemental protein in many dietary situations.

Energy in Corn Distillers Grains

Some speculated that the CDG available today might contain more energy than indicated by the “book” values. Therefore, we (Birkelo et al., 1994) conducted an experiment to determine the energy value of wet CDG for lactating cows. The research indicated that the digestible energy (DE), metabolizable energy (ME), and net energy for lactation (NE_L) of wet CDG were 1.86, 1.52, and 1.03 Mcal/lb DM, respectively. These values are 10 to 15% higher than published in the dairy NRC (2001) for DDGS. This likely reflects a higher energy value for newer generation distillers grains and does not necessarily reflect higher energy in wet than in dried CDG; that would have to be a separate comparison which has not been made.

Wet versus Dried Distillers Grains

One of the objectives of this presentation is to provide information about DDGS, but so far the presentation has contained information almost interchangeably about both wet and dried distillers grains. That is because the nutrient content of the dry matter is essentially the same for both wet and dried CDG except for possibly slightly lower RUP values for wet than for dried CDG (Firkins et al., 1984). I am not aware of any trials with lactating cows that directly compared wet versus dried CDG. The minimal amount of data comparing wet versus dried CDG with beef cattle would indicate that animal performance when fed wet CDG is just as good as or slightly better than when fed dried CDG. Likewise, I am not aware of direct comparisons between distillers grains versus distillers grains plus solubles. Again, I would expect similar animal performance with both products.

The main considerations between the uses of wet versus dried CDG are handling and costs. Dried products can be stored for extended periods of time, can be shipped greater distances more economically and conveniently than wet CDG, and can be easily blended with other dietary ingredients. However, feeding wet CDG avoids the costs of drying the product.

There are several factors to consider when feeding wet CDG that are not concerns when feeding DDGS. First, the product will not remain fresh and palatable for extended periods of time; 5 to 7 days is the norm. This storage time span will vary somewhat with environmental temperature as products will spoil and become unpalatable more rapidly in hot weather, but may be kept in an acceptable form as long as 3 weeks under cool conditions. Surface molds occasionally occur thus, there is usually some feed lost; a problem that wouldn't be a consideration with dried CDG, or DDGS. The addition of preservatives such as propionic acid or other organic acids may extend the shelf life of wet CDG, but scientific journal publications that document such results are difficult to find. In recent research, we at SDSU (Kalscheur et al., 2002, 2003, 2004) successfully stored wet CDG for more than six months in silo bags. The

wet CDG was stored alone or blended with soyhulls (Kalscheur et al., 2002) or with corn silage (Kalscheur et al., 2003). Some field reports indicate successful preservation of wet distillers grains for more than a year in silo bags.

How Much Distillers Grains can be Fed?

I recommend that dairy producers feed up to a maximum of about 20% of ration DM as distillers grains. With typical feed intakes of lactating cows, this would be about 10 to 12 lb of dried CDG or 33 to 37 lb of wet CDG per cow daily. There are usually no palatability problems and one can usually formulate nutritionally balanced diets with up to that level of distillers grains in the diet. For instance, with diets containing 25% of the dry matter as corn silage, 25% as alfalfa hay, and 50% concentrate mix, the CDG can likely replace most – if not all – of the protein supplement such as soybean meal and a significant amount of the corn that would normally be in the grain mix. In diets that contain higher proportions of corn silage, even greater amounts of DDGS may be useable. However, the need for some other protein supplement, protein quality (e.g. lysine limitation), and P concentration may become factors to consider. In diets containing higher proportions of alfalfa, less DDGS may be needed to supply the protein required in the diet, and in fact the diet may not be able to utilize as much DDGS. When feeding more than 20% distillers grains, one is likely to feed excess protein, unless forages are all or mostly corn silage and/or grass hay.

In previous research (Schingoethe et al., 1999) we fed slightly more than 30% of the ration DM as wet CDG with decreased DM intake but no decrease in milk production. However, recent research by our group (Hippen et al., 2003; 2004) in which as much as 40% of ration dry matter was fed as CDG indicated problems when the CDG provided more than 20 to 25% of the ration DM. With wet CDG (Hippen et al., 2003), DM intake decreased when diets contained more than 20% wet CDG with a corresponding decrease in milk production also. Gut fill may have limited DM intake of these wet diets because total DM intake may decrease when the diet is less than 50% DM, especially when fermented feeds are included in the diet (NRC, 2001). However, when dried CDG (DDGS) was fed, (Hippen et al., 2004) DM intake and milk production were still decreased when diets contained 27 or 40% dried CDG. Milk fat percentages also decreased when fed more than 13% DDGS. We don't know why that occurred because milk fat percentages were not adversely affected by distillers grains in our previous research (Liu et al., 2000; Nichols et al., 1998; Schingoethe et al., 1999) in which 20 to 30% distillers grains were fed.

There may be fewer off-feed problems when feeding distillers grains than when feeding corn, based on research with beef cattle. That is because, even though the distillers grains contains similar amounts of energy as corn, the energy in distillers grains is primarily in the form of digestible fiber and fat; in corn most of the energy is as starch. Ruminal starch fermentation is more likely to result in acidosis, laminitis, and fatty liver.

Distillers Grains Blended with Other Feeds

Several experiments have been recently conducted at SDSU in which wet CDG was blended with other high fiber feeds. Such approaches may be helpful in times when forage supplies are limited or expensive. For instance, a 70:30 (DM basis) blend of wet CDG and

soyhulls reduced the dustiness of soyhulls, reduced the seepage that is common with wet CDG, provided more desirable protein (21% CP) and P (0.6%) contents, and yet provided a high energy, high fiber feed (Kalscheur et al., 2002). Growth rates of heifers fed the blend were similar (2.7 to 2.8 lb/d) to gains when fed conventional diets (Kalscheur et al., 2004). When heifers were fed a blend of wet CDG (69% of DM) and corn stalks (31%), weight gains were less (2.3 lb/d) than when fed conventional diets (2.8 lb/d). Ensiling wet CDG alone or in combination with corn silage indicated that preservation of each could be enhanced by combining the feedstuffs with a 50:50 blend likely optimal (Kalscheur et al., 2003).

Other Corn Products as Feeds

There are several other corn products such as corn gluten meal, corn gluten feed, and corn distillers solubles that can also be fed to dairy cattle. I won't spend a lot of time talking about corn gluten meal and corn gluten feed, except for a sentence or two about each, because they are not included in the major thrust of this presentation. Corn gluten meal is a high protein (60% CP) and high RUP (55% of CP) feed that is a very good protein supplement but is best fed in combination with other protein supplements (Polan et al., 1991). Corn gluten feed is a good overall feed that is medium in protein (25% of CP), low in RUP (25% of CP), a good energy source ($NE_L = 0.86$ Mcal/lb), and sometimes priced competitively with other feed sources.

Corn distillers solubles will be discussed more extensively because they are a part of the same process that produces CDG. Distillers solubles are usually blended in with the distillers grains before drying to produce DDGS, but the solubles may be fed separately also. We (DaCruz et al., 1996) conducted one experiment with lactating cows in which condensed corn distillers solubles (CCDS) were fed at 0, 5, and 10% of total ration DM. The CCDS contained 28% DM and that DM contained 18% CP, 21.5% ether extract (fat), 12.5% minerals, and approximately 0.91 Mcal NE/lb. Milk production (75.2, 78.3, and 78.9 lb/d for 0, 5, and 10% CCDS diets) increased when fed the CCDS. Milk fat percentages (3.54, 3.33, and 3.43) were slightly lower ($P < 0.05$) when fed CCDS while milk protein percentages (2.93, 2.97, 2.95) were unaffected by diets. The added energy from fat in the CCDS likely contributed to the increased milk production but may have also caused the observed slight milk fat depression. Dry matter intakes (54.7, 53.8, and 49.6 lb/d) were similar for control and CCDS diets, although intake tended ($P < 0.10$) to be lower when fed 10% rather than 5% CCDS. It was concluded that feeding CCDS at 5% of ration DM is effective and profitable for dairy producers. There was no additional advantage to feeding CCDS at 10% of ration DM.

Conclusions

Corn distillers grains is a good protein and energy feed to include in rations for dairy cattle. The nutrient content of the dry matter in CDG is essentially the same for both wet and dried CDG. Nutrient content is also similar whether or not the solubles are added to the distiller grains to make DDGS, with the exception of the higher P content with the solubles added.

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Table 1. Milk production response to diets containing corn distillers grains as the supplemental protein source.

Experiment	Protein supplement					
	SBM	SBM RPLM	CDG	CDG +RPLM ¹	BLEND	BLEND +RPLM
	(milk, lb/d)					
Schingoethe et al., 1983	59.5	---	60.8 ³	---	---	---
Schingoethe et al., 1999	67.7	---	67.9 ³	---	---	---
Nichols et al., 1998	75.6	75.0	77.8 ⁴	80.9 ³	---	---
Liu et al., 2000	---	---	71.9 ⁴	69.9	72.3	72.3
Owen & Larson, 1991	74.5	---	75.6 ⁵	---	---	---
Powers et al., 1995	59.1	---	61.1 ^{6*}	---	---	---
Powers et al., 1995	59.1	---	61.3 ^{7*}	---	---	---
Powers et al., 1995	59.1	---	59.3 ⁸	---	---	---

¹RPLM: ruminally protected lysine and methionine

²BLEND: supplemental protein was approximately 25% from CDG, 25% from fish meal, and 50% from soybean meal (SBM).

³Wet CDG

⁴Dried CDG

⁵Dried CDG plus solubles

⁶Whiskey dried CDG plus solubles

⁷Fuel-ethanol dried CDG plus solubles

⁸Darker fuel-ethanol dried CDG plus solubles

* Production was greater than with SBM, P < 0.05

USING DISTILLERS GRAINS IN DAIRY CATTLE RATIONS

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Distillers grains are co-products produced from the fermentation of grains for alcohol. Traditionally, alcohol was produced mainly for the beverage liquor industry, but in the last 20 years its use as an alternative fuel has increased significantly. This increased demand has led to the development of several ethanol production plants in Minnesota and the surrounding area. In 1996, it is estimated 135,000 tons of distillers grains will be produced from current plants with production doubling or tripling over the next five years as more ethanol plants begin operation. Thus, the opportunity exists for using a substantial quantity of distillers grains in dairy rations.

When grains are fermented to alcohol, approximately one-third of the dry matter (DM) is recovered in co-products. The two basic products at the end of the fermentation process are coarse, unfermented grains and a liquid fraction known as thin stillage containing small particles of grain, yeast and soluble nutrients. These two products are further processed into the following four co-products: 1) distillers dried grains (**DDG**), 2) distillers dried solubles (**DDS**), 3) distillers dried grains with solubles (**DDGS**), and 4) condensed distillers solubles, 30 to 40% DM (**CDS**). Both the CDS and DDS are made from thin stillage through partial (CDS) or complete (DDS) drying. Dried distillers grain with solubles is produced by adding a portion of the thin stillage back to the unfermented grain fraction at the time of drying. The two primary co-products used in the feed industry are DDG and DDGS.

Alcohol can be produced from one or any combination of cereal grains. The most commonly used grains are corn, milo, wheat, barley and rye. The grain used in the largest quantity is used to name the resulting product. For example, corn distillers grains would be produced from a fermentation batch where corn was the primary grain used.

As the names imply, most distillers grains are produced in a dry form. This results in ease of handling, storage and shipping to local or foreign markets. The effects of drying on nutrient availability have been of some concern and debated in various research studies. Wet distillers grains are available in some areas. This reduces the energy costs of drying but increases their perishability and handling problems for the feeder.

Nutrient Composition

The typical nutrient content of corn-based distillers grains is shown in Table 1. In general, distillers grains are devoid of starch but a good source of energy, protein, fiber and phosphorus. The nutrient content of distillers grains is about three times more concentrated than the nutrients in the original grain before fermenting. Yeast cells also are quite high in distillers grains (10).

The yeast species *Sacchsromyces cerevisiae* is commonly used for fermentation, as it is an efficient producer of alcohol. Yeast concentrations often reach 150 million cells per cubic centimeter in mashes after just 26 hours of fermentation.

Table 1. Nutrient composition of common corn distillers co-products.¹

Nutrient ²	Distillers grains (DDG)	Distillers grains + solubles (DDGS)	Condensed distillers solubles (CDS)
DM, %	94	92	93
CP, %	23	25	30
NE _L , Mcal/lb	.90	.93	.93
TDN, %	86	88	88
Fat, %	10	10	9
ADF, %	17	18	7
NDF, %	43	44	23

¹ NRC, 1989 (14).

² All nutrients except DM expressed on a DM basis.

The nutrient content of distillers grains can be influenced by a number of factors. The primary factors are the type of grain (Table 2), milling process, grain quality, fermentation process, drying temperature and amount of solubles blended back into the unfermented fraction at the time of drying. Chase (4) showed ranges in the DM content of DDGS as follows: crude protein (CP) - 22 to 33%, neutral detergent fiber (NDF) - 29 to 64%, and fat - 2 to 20%. Purchasers of distillers grains must be cognizant of variations in nutrient content. When purchasing distillers grains, it is important to know what grain or combination of grains were used in the fermentation. Distillers grains should be tested for DM, CP, acid detergent fiber (ADF), NDF, ADF insoluble nitrogen (ADIN) and fat.

Of particular interest to dairy nutritionists is the undegradable intake protein (UIP) or “bypass” protein content. Values published by the NRC (14) for UIP of corn DDG and DDGS are 54 and 47% of the CP. More recent results have shown corn-based DDGS to vary from about 45% (17) to 55% (9). Stern et al. (20) analyzed five samples of distillers grains and found a UIP of 56±8% with an intestinal digestibility of the UIP at 81±5%. Grings et al. (9) reported the intestinal digestibility of UIP in DDGS was 93%. Soluble intake protein (SIP) of distillers grains was estimated by Chase (4) to be about 15% of the CP, but more recent research (17) has shown it to be about twice that value (28.5% of the CP).

The amino acid profile of two corn and one milo DDGS is shown in Table 3. With today’s emphasis on balancing amino acids in the diets of dairy cows, knowing the amino acid content and the variation that can occur in high bypass protein sources like DDGS is important. Dong et al. (16) evaluated the amino acid profiles of several wheat DDGS and found profiles in the DDGS to be similar to the whole grain before fermentation.

Table 2. Nutrient composition of some non-corn distillers dried grains with solubles (DDGS).¹

Nutrient	Barley DDGS ²	Rye DDGS ³	Wheat DDGS ⁴
DM, %	88		96
CP, %	29	29	44
ADF, %	29	20	16
NDF, %	56		36
ADIN, % of CP	39		10

¹ All nutrients except DM expressed on a DM basis.

² Weiss et al. (22).

³ Shelford and Tait (18).

⁴ Boila and Ingalls (3).

Table 3. Amino acid profile of corn and milo distillers dried grains with solubles (DDGS).

Amino acid	Corn DDGS ¹	Corn DDGS ²	Milo DDGS ¹
	----- % of DM -----		
Lysine	.70	.47	.95
Methionine	.60	.63	.50
Histidine	.70	.76	.69
Arginine	1.05	1.05	2.40
Threonine	.93	1.01	.92
Leucine	2.23	3.42	4.98
Isoleucine	1.52	1.12	.92
Valine	1.63	1.55	1.07
Phenylalanine	1.51	1.27	1.47
Tryptophan	.20		

¹ Distillers Feed Research Council, Des Moines, IA.

² Powers et al. (17).

Grains are generally low in fiber and considered an insignificant fiber source in diets for dairy cattle. However, concentration of the fiber by removal of starch during fermentation results in DDG and DDGS being a very good source of nonforage fiber for dairy cattle. The NDF content of distillers grains is typically 35 to 40% of the DM (Table 1). However, the fiber is very short in particle length and, therefore, raises questions as to its effectiveness in stimulating cud chewing. The effective fiber values of nonforage fiber sources have been determined by either their physical characteristics and how they contribute to rumen mat formation and cud chewing or by

their ability to support a “normal” milk fat percentage when used to replace forage fiber in a diet (1, 8). Bhatti and Firkins (2) indicated the digestion of NDF in distillers grains is rather slow initially, but once initiated the digestion rate was relatively fast (.0626/hour). The slow initiation could be a reflection of the low water holding capacity (.062g/g of insoluble DM) of NDF in distillers grains, as fiber must be hydrated before digestion by bacteria (2). The slow initial digestion rate in combination with a small particle size can result in a fast rate of passage from the rumen. Thus, the physical effectiveness of NDF in distillers grains to stimulate cud chewing appears to be quite limited.

The use of milk fat percentage as a measure for effective fiber is based on the digestion of fiber in the rumen and not the physical attributes needed for stimulation of cud chewing. Firkins (8) indicated the NDF in nonforage fiber sources like DDS or DDGS are less than half as effective as forage NDF sources in stimulating cud chewing. Thus, the effective fiber values for nonforage feeds based on milk fat percentage represents their ability to substitute for nonfiber carbohydrates (NFC) in diets rather than stimulate cud chewing. Using the milk fat percentage method, Clark and Armentano (5) determined DDG had an effective NDF value equal to that of alfalfa haylage. In comparison with corn silage NDF in maintaining milk fat percentage, Staples et al. (19) found DDGS NDF was 68% as effective. However, in diets high in corn silage and considerably above NRC minimum fiber recommendations the effectiveness of NDF in DDGS was negative. In other words, replacing corn and soybean meal with DDGS in diets high in NDF decreased milk fat percent.

Evaluating Protein Quality

Extensive heating of distillers grains during the drying process has raised questions about the nutrient availability, especially protein, in DDS and DDGS. The effects of excessive heating on reducing protein availability to animals has been well documented. Acid detergent insoluble nitrogen (ADIN) or the amount of nitrogen in the ADF fraction has been used as an indicator and measure of the protein availability reduction in a feed due to heat damage. Chase (4) extensively reviewed the use of ADIN as a method utilized to estimate heat damaged protein in distillers grains and other co-products. He concluded that ADIN, although not perfect, can be a good “index” for measuring heat damage in feeds.

Nakamura et al. (13) found a range in ADIN from 7.8 to 27.9% of the total nitrogen in distillers grains from seven different distillers. A relationship between ADIN and “bypass” protein content of the distillers grains was evident ($r^2 = .55$); however, the correlation with true digestibility of nitrogen in distillers grains was very low ($r^2 = .24$). An average of 78% of the ADIN in the seven samples of distillers grains was digested by sheep. Additional research by Klopfenstein (11) suggested some of the nitrogen associated with ADIN can be absorbed from the digestive tract but may not be efficiently utilized by the animal for growth. The biological availability of amino acids such as lysine appears to be reduced during the heating process.

Protein solubility is not a good estimator of ADIN content in distillers grains. Both Chase (4) and Powers et al. (17) demonstrated either a very poor or no correlation between ADIN and soluble protein, expressed as percent of CP, content in distillers grains.

An early biological indicator of heat damage in distillers grains may be a reduction in milk protein percentage when fed to lactating cows. Van Horn et al. (21) observed a reduction in milk protein percentage in cows fed DDGS with a high ADIN content (32.9% of the total nitrogen) compared to cows fed soybean meal. Others (15, 16) have observed similar results. However, it is unclear whether the reduction in milk protein percentage was caused solely from a high ADIN content in distillers grains or an imbalance of amino acids in these diets, namely low lysine, created by the substitution of distillers grains for soybean meal. When feeding diets containing both soybean meal and DDGS, Powers et al. (17) observed a slight decline in milk protein percentage only when the DDGS source contained more than 20% of the nitrogen in the ADIN fraction.

There appears to be conclusive evidence that animal performance is diminished in some manner when heat damaged protein feeds are fed. The exact level of ADIN in DDG or DDGS where a depression in animal performance occurs is unknown. However, color of distillers grains appears to be associated with amount of ADIN (17). Good, high quality distillers grains will have a honey golden to caramelized golden color. Color progressing towards dark coffee grounds is an indicator of excessive heating during the drying process and the potential for high levels of ADIN.

Research Studies with Distillers Grains

Early research work on feeding distillers grains to dairy cattle has been summarized in a 1991 review by Chase (4). Performance results from these studies were inconsistent. In studies where increases in milk yield or milk components were found, the forage base of the diet was alfalfa or a mixture of alfalfa and corn silage. Decreases in milk production or milk components from feeding distillers grains were associated with high levels of ADIN in DDGS and with all or very high levels of corn silage in the diet. Current knowledge would indicate that the studies reporting lowered milk production resulted from reduced microbial growth in the rumen and a low dietary lysine content as the primary source of dietary protein was from corn products.

Since 1991, five research studies evaluating the use of distillers grains in lactating dairy cow diets were found. These are summarized below and in Table 4.

Owen and Larson (15) reported the results of a study comparing DDGS and soybean meal in diets for early lactation cows. The dietary DM fed in this study consisted of 50% ammoniated corn silage and 50% concentrate. Milk production of cows fed DDGS or soybean meal was equal when DDGS was included in the diet at 19% of the DM (low CP diet - 14.5%) but decreased when DDGS was included at 36% of the DM (high CP diet - 18%). The authors concluded that the poor performance of cows fed the high DDGS diet was from poor digestibility and a shortage of available lysine. The decrease in milk protein percentage on both the high and low CP diets with feeding of DDGS compared to soybean meal also indicates available lysine was deficient in these corn based diets (Table 4).

The substitution of DDGS for ground corn in early lactation diets was evaluated by Grings et al. (9). The diets were alfalfa-based and contained 61% concentrate with DDGS at 0, 10.1, 20.8 and 31.5% of the dietary DM. Crude protein content of the diets increased with increasing DDGS amounts (13.9, 16.0, 18.1 and 20.3%). Milk yield and milk protein percentage increased linearly with increasing dietary CP (Table 4). Dry matter intakes were not different among the four treatments; however, fat and UIP intakes increased and NFC intakes decreased as DDGS in diets increased. The beneficial response to increasing CP in alfalfa-based diets up to 18.1% by the addition of DDGS was attributed to an increased intake of CP, UIP and essential amino acids. Intestinal availability of UIP in the DDGS fed in this study was determined to be 93%.

Using a Latin square design with mid-lactation cows, Clark and Armentano (5) determined the effect of replacing alfalfa NDF with NDF from DDG on milk production and composition. Although this was only a short term study with objectives to measure fiber effectiveness, substituting DDG for 12.7% of the alfalfa DM in the diets resulted in both a milk production and milk protein percentage increase (Table 4).

Powers et al. (17) compared the performance of mid- and early-lactation cows fed 14 or 18% CP diets containing DDGS from three different sources or soybean meal with and without blood meal. Amounts of DDGS in diets were 13% of the DM in the 14% CP diet and 26% of the DM in the 18% CP diet. The three sources of the DDGS are designated as 1, 2 and 3. All diets were a 50:50 forage to concentrate ratio (DM basis) with corn silage as the sole forage. The DDGS from sources 1 and 2 (DDGS-1 and DDGS-2) were lower in ADIN (13 and 17% of the CP, respectively) and lighter in color than the third source (DDGS-3) with 21% ADIN. Production results are shown in Table 4. Dry matter intakes were not affected by either source or amount of CP in the diet. Milk productions from cows fed either DDGS-1 or DDGS-2 were higher than those of cows fed soybean meal. Milk production of cows fed DDGS-3 was similar to cows fed soybean meal. Milk yields were higher with 26% DDGS than with 13% DDGS included in diets. Milk protein percentage was decreased with feeding DDGS-3. The authors indicated that quality differences in DDGS do affect animal performance and need to be considered when DDGS is fed. They concluded that color and ADIN content of DDGS along with milk protein percentage are good indicators of DDGS quality.

Staples et al. (19) evaluated the effects of DDGS on the performance of dairy cows fed corn silage-based diets varying in concentrate to forage ratio. Three concentrate to forage ratios were fed (70:30, 55:45 or 40:60) with either 0 or 20% DDGS in the dietary DM. With increasing concentrate level in the diet, a linear increase in DM intake and milk production and a linear decrease in milk fat percentage was observed (Table 4). Feeding DDGS in replacement of corn and soybean meal resulted in about 2.5 lb more milk per day. The effectiveness of NDF in DDGS in elevating milk fat percentage when fiber deficient diets are fed was determined to be about 68% as effective as corn silage NDF.

Table 4. Distillers grains production trials.

Reference	CP	Conc	DDGS	Production measures			
				DM	Milk	Fat	Protein
----- % of diet DM -----				----- lb/day -----	----- % -----		
15	Base forage - Ammoniated corn silage						
	13.9	50	9	49.0	71.7	3.55	2.89
	14.6	50	0	52.2	74.5	3.65	2.99
	14.6	50	19	55.3	75.6	3.62	2.76
	18.7	50	0	52.9	75.2	3.68	3.03
	17.7	50	37	50.7	62.8	3.76	2.77
9	Base forage - Alfalfa						
	13.9	61	0	55.8	83.3		2.63
	16.0	61	10.1	58.0	88.6		2.66
	18.1	61	20.8	58.2	92.4		2.78
	20.3	61	31.6	58.4	92.6		2.80
5	Base forage - Alfalfa						
	19.9	56.4	0	50.3	67.5	3.30	2.98
	20.1	69.1	12.7	53.6	71.7	3.27	3.09
17	Base forage - Corn silage						
	14	50	0	53.1	58.6	3.38	3.14
	14	50	13 (1) ¹	52.9	58.9	3.53	3.13
	14	50	13 (2)	52.4	61.0	3.45	3.15
	14	50	13 (3)	52.0	58.2	3.39	2.95
	18	50	0	51.8	60.3	3.49	3.17
	18	50	26 (1)	54.2	63.0	3.52	3.26
	18	50	26 (2)	53.2	62.2	3.34	3.12
	18	50	26 (3)	53.8	60.4	3.59	3.08
19	Base forage - Corn silage						
	16.1	40	0	46.7	56.1	3.78	
	16.5	55	0	51.3	59.1	3.60	
	15.8	70	0	54.2	61.4	3.44	
	16.4	40	20	46.1	60.3	3.69	
	16.5	55	20	50.9	60.7	3.64	
	16.4	70	20	51.7	63.9	3.57	

¹ Number in () indicates source of DDGS (see text for explanation).

Feeding Recommendations

Distillers grains are a palatable, high energy, fiber feed and a good source of UIP for use in feeding dairy cows. Based on the research reviewed, DDGS or DDG can comprise up to 26% of the dietary DM fed to dairy cows. The basic limit as to the quantity of distillers grains that can be fed will be determined by the CP and UIP content of the diet. Because distillers grains are relatively high in UIP (55% of the CP), feeding high amounts of distillers grains can result in low

rumen ammonia levels and deficiency of DIP in the diet. Also, the profile of amino acids in the diet as well as those presented to the intestine must be considered when distillers grains are included in rations. Balancing diets for SIP, DIP and UIP along with consideration of CP, lysine and methionine can minimize many of the problems and negative effects observed with feeding distillers grains in research studies.

In addition to the above, it is advisable to limit the amount of CP coming from corn sources in a ration to less than 60% of the total CP. Corn protein sources would include corn silage, corn grain, corn DDGS, corn gluten meal and corn gluten feed.

The NDF in distillers grains is effective in maintaining milk fat percentage but is relatively ineffective at stimulating cud chewing. Therefore, distillers grains is an effective substitute for NFC in diets but has limited forage fiber replacement abilities. If the minimum amount of forage in the diet meets the physically effective fiber requirement for cud chewing, then distillers grains can be used to replace any additional forage fiber needed in the diet. The effective replacement rate of NDF in distillers grain for forage fiber is considered to be about 66%. Therefore, for every 1 lb of forage NDF needed in a diet, 1.5 lb of NDF from distillers grains must be added.

Economic Considerations

Several approaches are available to estimate the economic value of distillers grains as well as other feeds (7). In any pricing considerations, nutrient variability along with ease of handling and storage, overall feed quality and animal acceptance must be considered.

The preferred method of pricing is a least-cost ration as this evaluates the use of all feeds under consideration for the diet under a well-defined set of nutrient requirements. However, in many situations a quick comparison of one feed against one or two other feeds based on protein and energy value is all that is desired. The following methods can be used to obtain a quick comparison of economical value for DDGS:

1. Price based on cost/unit of CP or UIP.

$$\$/\text{unit of CP or UIP} = \$/\text{unit of feed} / (\text{unit of feed} \times \text{DM} \times \text{CP or UIP})$$

Example:

Cost of CP from soybean meal (49.9% CP, DM basis; 89% DM)

$$\$/\text{lb of CP} = \$250/\text{ton} / (2000 \text{ lb} \times .89 \times .499) = \$.28/\text{lb of CP}$$

Cost of CP from DDGS (28% CP, DM basis; 92% DM)

$$\$/\text{lb of CP} = \$150/\text{ton} / (2000 \text{ lb} \times .92 \times .28) = \$.29/\text{lb of CP}$$

Similar calculations can be made for UIP

Example:

$$\begin{aligned} \text{DDGS (where UIP is 55\% of CP)} \\ \text{\$/lb of UIP in DDGS} &= \$150/\text{ton} / (2000 \text{ lb} \times .92 \times .28 \times .55) \\ &= \$.53/\text{lb of UIP} \end{aligned}$$

- Equation to price DDGS in relation to corn (energy source) and soybean meal (CP source).

All feeds must be priced on a common unit basis (\$/cwt or \$/ton) and on an equal DM basis such as air dry (90% DM).

$$\text{Corn} = \$7.14/\text{cwt} \qquad \text{Soybean meal} = \$12.50/\text{cwt}$$

$$\begin{aligned} \text{\$/cwt of DDGS} &= (\text{\$ of corn} \times .531) + (\text{\$/cwt of soybean meal} \times .514) \\ &= (\$7.14 \times .531) + \$12.50 \times .514 \\ &= \$10.22/\text{cwt or } \$204.40/\text{ton} \end{aligned}$$

- Another way of pricing DDGS based on protein and energy is against a mix of soybean meal, corn and fat which is equal in CP and energy to the DDGS. An example of a 100 lb mix equivalent to DDGS of 25% CP, 9% fat and 86 Mcal of NE_L (as fed basis) is:

	lb/100 lb of mix	x	\$/lb	=	\$/100 lb of mix
Soybean meal	47.5	x	.1250	=	5.94
Corn	46.0	x	.0714	=	3.28
Tallow	6.5	x	.25	=	1.62
Total					\$10.84 / 100 lb of DDGS

Feeding Wet Distillers Grains

For some dairy producers, feeding wet distillers grains (WDG) directly from an alcohol plant may be an option. Very little information is available on feeding WDG, especially to dairy cattle. Klopfenstein and Stock (12) summarized several studies conducted by the authors on feeding WDG to feedlot cattle. Dry matter content of WDG averaged 31.4%. Nutrient composition of WDG is slightly different than DDG. The WDG fed in their research studies contained more starch and ethanol and less protein than typically found in DDG. The energy value for gain determined from feeding trials was 1.28 to 1.69 times greater for WDG than corn. No differences in protein efficiency were found between DDGS and WDG when fed to growing calves. As with any high moisture feed, the handling, storage, storage loss and transportation costs must be considered in the usage and economic value of WDG.

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USES OF CORN COPRODUCTS IN BEEF AND DAIRY RATIONS

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USE OF CORN COPRODUCTS FOR BEEF CATTLE

Distillers grains (**DG**) are an excellent ruminant feedstuff. They are an excellent source both of energy and protein. In the production of alcohol, the starch, which is about two-thirds the composition of corn grain, is fermented to alcohol and CO₂. The remaining nutrients are then concentrated by a factor of three. Corn protein of 10% is concentrated to 30% and fat (oil) from 4 to 12%. Fiber is concentrated from 14 to 42%. The fiber is highly digestible and the fat has about three times the energy of starch. The protein is high in undegraded intake protein (**UIP**).

The DG can be used as both a protein source and an energy source for growing cattle and for finishing cattle. For growing cattle, the value of the UIP is most important.

The DG are normally available for use in feedlot finishing diets in two forms, dried distillers and wet distillers grains. In general, there are two nutritional philosophies regarding their use in feedlot finishing diets. The DG can be fed at 6 to 15% of the diet dry matter (**DM**), serving primarily as a source of supplemental protein. When fed at higher levels (greater than 15% of the diet DM), the byproduct's primary role is as a source of energy replacing corn grain. Other than DM content (wet DG, 35-45%; dried DG, 90-95%), the chemical composition of the two products is similar.

Dried DG is routinely fed as a supplemental protein source; however, the drying process appears to reduce the energy value of the DG. Ham et al. (1994) demonstrated a 9% improvement in feed efficiency when dried DG replaced 40% of the dry-rolled corn in finishing diets (Table 1). However, this improvement was only 50% of that observed when wet DG byproduct replaced a similar amount of dry-rolled corn. Drying cost significantly increases the commodity price for the DG. The dried DG is routinely priced relative to other supplemental protein sources like soybean meal. Therefore, when priced on an energy basis (relative to corn), the expected improvement in animal performance is not large enough to offset the increased ration cost associated with higher inclusion levels.

Wet DG are commonly fed at higher levels in the diet to supply both protein and energy to the animal. There are numerous advantages to using wet DG. For the dry-milling plant, the energy cost associated with drying the product can be significantly reduced or eliminated. This should allow for an overall increased energy yield for each bushel of corn processed. The major downside of using wet DG is transportation costs associated with the movement of water.

Experiments evaluating the use of wet DG in feedlot diets are available (DeHaan et al, 1983; Farlin, 1983; Firkins et al., 1985; Ham et al., 1994; Fanning et al., 1999; Larson et al., 1993; Lodge et al., 1997a; Trenkle, 1997a; Trenkle, 1997b). In the experiments with finishing cattle, the replacement of corn grain with wet DG consistently improved feed efficiency. Larson et al. (1993) replaced dry-rolled corn with 5.2, 12.6, or 40% (DM basis) wet DG (Table 2). With the

first two levels of byproduct (5.2 and 12.6%), these researchers observed a 7% increase in feed efficiency above the basal dry-rolled corn diet. But, when the inclusion level was increased to 40% of the diet DM, the improvement in feed efficiency was 20% above the dry-rolled corn diet. In other published experiments (Ham et al., 1994; Fanning et al., 1999; Lodge et al., 1997a), the inclusion level of the wet distillers byproduct has been 30 to 40% of the diet DM. These experiments consistently suggest a 15 to 25% improvement in feed efficiency when 30 to 40% of the corn grain is replaced with wet DG.

Eleven experiments were summarized where wet DG was compared with corn as an energy source for finishing cattle (Table 3). The wet DG replaced 12.6 to 50% of the diet (corn). The data were summarized into three situations. First is the control diet based on dry-rolled corn. Second is when wet DG replaced corn at a low level in the diet (12.6 to 28%). The third situation is where wet DG replaced corn in the diet at 30 to 50% of dietary DM.

At the low level (average 17.4%) of wet DG feeding, the energy value was 152% that of corn. At the high level of feeding, the value decreased to 136% the value of corn. We can then calculate the value of the wet DG as 124% the value of corn when fed between 17.4 and 40% of the diet.

We believe there are very good explanations for the change in relative feeding values as wet DG increases in the diet. We believe the first increments fed (up to 17.4%) supply nutrients such as protein that may be of value to the cattle, but more importantly, reduce the acidosis that occurs in the control diet. The wet DG contains protein and fat which supply energy to the animal, but it does not contain the starch that leads to acidosis. Further, the fiber (hull) in the wet DG is highly digestible but adds fiber to the diet and reduces acidosis. So, the very high value of the wet DG (152%) at low level feeding is probably due to factors other than the strict energy value of the nutrients contained therein.

The value when fed above 17.4% of the diet is probably due to the high fat content of the wet DG and the high content of bypass protein. Fat has about three times the energy value of starch for cattle and bypass protein has about 30% more energy than starch. The value from feeding trials was determined to be 124% the value of corn. By calculating the theoretical energy value based on the bypass protein and fat contents, we estimate the energy value of wet DG to be 120% the value of corn. This calculation gives confidence in the value obtained from feeding trials.

Typical feedlot diets contain about 85% corn. The starch in the corn is the energy source used by the cattle. However, the starch is rapidly fermented by the rumen microorganisms to organic acids. The overproduction of the organic acids causes acidosis followed by reduced feed intake and reduced gains (Stock and Britton, 1993; Stock et al., 1995). Distillers byproducts have essentially all of the starch removed leaving protein, highly digestible fiber, and fat. The feeding of the byproducts appears to reduce acidosis and enhances feed efficiency.

There are at least three factors involved in the higher feeding value for distillers byproducts (protein, energy, acidosis). Based on the limited data available regarding the level of wet distillers byproduct in the diet, the economic value of the byproduct varies as the level fed in the

diet changes. Also, as the level fed increases, more is fed per animal per day and more total byproduct would be fed. The precise relationship between level of byproduct in the diet and both the feeding value and economic value remains elusive.

Corn gluten feed is the other important corn milling byproduct. It is produced by the wet milling process and the byproduct is quite different from DG. Gluten feed contains the fiber from the corn but does not contain the fat or the zein protein (the high bypass protein) that is in the distillers grains. The gluten feed contains steep liquor, distillers solubles, corn bran, and germ meal in varying combinations.

Stock et al. (2000) have summarized the feeding values of two different gluten feeds for feedlot cattle. For the first product (Table 4), the feed efficiency (feed:gain ratio) was essentially equal between the control (corn) diets and the diets containing gluten feed. This suggests equal energy value for gluten feed and corn. Product B (Table 5) had dietary feed efficiencies 5% better than the control indicating higher energy value for the gluten feed than for the corn grain it replaced. Gluten feed, like DG, helps control acidosis. The gluten feed is actually less digestible than corn grain (Bierman et al., 1995) but has equal or higher apparent energy in feedlot diets because it controls acidosis.

Gluten feed is an excellent protein and energy supplement for growing calves or beef cows. It was used as a supplement for growing calves grazing corn stalks. In the range of 5 to 6 lb DM per day, gain was optimized and the supplemental needs for protein and phosphorus were met with gluten feed (Figure 1). Jordon et al. (2001b) have shown it to be a very cost effective supplement for growing calves.

USE OF CORN COPRODUCTS FOR DAIRY CATTLE

Coproducts of wet and dry milling, most notably DG and corn gluten feed (**CGF**), have been used conservatively as forage and concentrate replacements in diets for lactating dairy cattle. Commonly, DG and CGF are fed at $\leq 20\%$ of the dietary DM, but recent research indicates that substantially more can in fact be fed, especially for CGF. Maximizing the use of these corn coproducts in ruminant diets will become increasingly important as more ethanol plants are built in the near future.

An understanding of the chemical composition of these coproducts enables us to effectively position them in dairy formulations. Both contain 40 to 45% NDF which is highly digestible (6-8%/h digestion rate) due to low lignification and can therefore replace starch (10-30%/h digestion rate) and reduce the risk of ruminal acidosis (Allen and Grant, 2000). Due to their small particle size, both coproducts have $<15\%$ physically effective NDF and so do not stimulate much rumination (Clark and Armentano, 1993; Allen and Grant, 2000). Consequently, particle size of forage is a critical issue when either coproduct replaces forage. Major compositional differences between DG and CGF include lipid and protein fractions. Distillers grains, wet or dry, contain 30 to 35% CP, of which $\sim 55\%$ is ruminally undegradable protein (**RUP**). In contrast, CGF contains 20 to 25% CP and only 25 to 30% RUP. The lipid content of DG is 10 to 15%, but $<3\%$ for CGF. These differences in physicochemical properties have positioned CGF primarily as a source of digestible NDF, whereas DG have been positioned as a source of RUP.

However, there is no reason why, with proper supplementation and forage combinations, that both coproducts could not serve as sources of RUP and energy. This section will focus on recent research aimed at optimizing the nutritional properties of these two coproducts and maximizing incorporation of them into diets for lactating dairy cows. For more comprehensive summaries of milk production responses to CGF or DG, refer to reviews by Chase (1991) and Schingoethe (2001).

Corn Gluten Feed for Dairy Cows

A summary of beef feedlot research (Stock et al., 2000) indicated that efficiency of gain was improved by 5.1% when diets contained 25 to 50% wet CGF (corn bran:steep liquor, 1:1 DM basis) were compared with dry-rolled corn. This positive response was likely due to reduced ruminal acidosis and increased DMI. Ruminal acidosis is a significant concern when feeding dairy cows as well because of the need for optimal ruminal fiber digestion in the presence of substantial amounts of starchy concentrate feeds. Corn bran is rapidly and extensively digested in the rumen. Consequently, the dilution of starch with NDF from CGF results in slower rates of fermentation, reduced acid load in the rumen per unit of fermentation time, and the ability to feed a highly digestible diet with low risk of ruminal acidosis.

Nonforage sources of fiber, such as CGF, do not stimulate rumination as effectively as forages. Therefore, it is necessary for dietary forage to have adequate particle length for normal rumination when replacing forage. Additionally, forage of longer particle length forms a digesta mat that more effectively filters and entangles smaller particles allowing greater time for fermentation in the rumen (Welch, 1982). Allen and Grant (2000) evaluated the effect of ruminal mat consistency on passage and digestion kinetics of wet CGF in dairy cattle. Table 6 summarizes the diets and key responses. Two diets were formulated to contain ~40% alfalfa, 24% wet CGF, plus a corn and soybean meal-based concentrate. One diet contained alfalfa silage and the other contained a 1:1 blend of alfalfa silage and coarsely chopped alfalfa hay of similar quality. Compared with the diet without added hay, the diet with added hay had 59% more long particles, a 37% increase in ruminal mat consistency, a 27% increase in rumination, equal NDF intake, but a 35% reduction in passage rate of CGF, an increase in ruminal NDF digestion of nearly 40%, and an increase in 4% fat-corrected milk (FCM) of 5.5%. Both diets contained 24% wet CGF, and this research points out the potential to manipulate passage and digestion of CGF to maximize NDF fermentation in the rumen. Though the research has not been conducted, presumably a similar response would be observed for DG since they have similar particle size and specific gravity as CGF. Fibrous coproducts can contribute more to highly digestible diets than previously thought if their passage and digestion kinetics are optimized, in addition to ensuring adequate physically effective NDF in the total diet.

One problem with the design of much previous research that evaluated CGF for dairy cows has been that diets were balanced for CP, but not metabolizable protein (**MP**). Wet CGF contains twice as much CP as corn, but less MP (Krishnamoorthy et al., 1982; Stock et al., 2000). Thus, control diets containing corn grain, which use soybean meal to balance for CP, may contain CP concentrations similar to CGF diets, but these control diets also contain substantially greater amounts of MP. If MP is not adequate for diets containing CGF, erroneous conclusions may be made concerning their nutritional value. Several studies have indicated that $\leq 20\%$ dietary wet

CGF is optimal for milk production (Droppo et al., 1982; Gunderson et al., 1988; Schroeder and Park, 1997). However, MP may have been limiting milk production rather than energy or effective NDF beyond 20% inclusion.

Recently, a series of studies (Boddugari et al., 2001) were conducted to develop a new wet CGF product based on ingredients from the wet milling process to enhance the MP content and to determine the maximal amount of this product that could be incorporated into the diet. The hypothesis was that a properly formulated wet CGF product could be fed in amounts much greater than currently practiced by the dairy industry. The wet corn milling feed product (**CMP**) developed was composed of corn bran, fermented corn extractives (steep liquor), corn germ meal, and additional sources of RUP to increase the MP content of the product. The CMP contained 23.1% CP, 43.0% RUP (% of CP), 13.7% ADF, 40.3% NDF, and 2.6% lipid (DM basis). For comparison, the nutrient profile of the wet CGF from the wet milling plant that provided the CMP is 22.5% CP, 30.0% RUP, 14.0% ADF, 43.0% NDF, and 2.5% lipid. Clearly, the major difference was an improvement in the RUP content of the CGF. In the first trial, four diets were evaluated that contained 54.3% forage with the CMP replacing either 0, 50, 75, or 100% of the concentrate. All of the diets containing CMP resulted in 7.8% lower DMI, equivalent milk production, and 13.6% greater efficiency of FCM production than the control diet. In a subsequent trial, the 100% concentrate replacement diet served as the control diet and 15, 30, or 45% of the forage was replaced with CMP. Production of 4% FCM and efficiency of FCM were unaffected by diet, but rumination decreased for the 30 and 45% replacement diets, although ruminal pH was unaffected. These two trials demonstrated, at least in short-term studies (4-wk periods), that up to 70% of the dietary DM could be comprised of CMP, which is far greater than previously published studies.

A final study (Boddugari et al., 2001) was designed to evaluate an optimal amount of CMP in the diet for early lactation cows. Cows were assigned, from day 1 to 63 of lactation, to either a control diet (no CMP) or a diet containing 40% CMP. The 40% level was chosen because the maximal effect on efficiency of FCM production was achieved at 50% concentrate replacement and 30% forage replacement in the previous trials. Table 7 summarizes the production responses to these diets. The diet containing the CMP resulted in a 21% greater efficiency of FCM production than the control diet. This series of studies showed that up to 70% of the diet can be replaced by a properly formulated wet CGF product, and that 40% of the dietary DM may be an optimal amount to feed. A key concept is that by correcting a deficiency in the coproduct feed (MP in this case), we were able to feed more and substantially increase the amount of energy the cow captured from digestible NDF, rather than starch, which should result in healthier, more productive cows long-term.

Distillers Grains for Dairy Cows

Most research has focused on DG as an alternative protein source to soybean meal (Owen and Larson, 1991 as an example). However, DG also is an excellent source of energy due to its high content of digestible NDF and lipid. In a recent review, Schingoethe (2001) suggested a maximum of 20% DG in the dietary DM fearing potential palatability problems and excessive protein consumption above this amount. However, a recent trial (Schingoethe et al., 1999) found

that diets containing 31.2% wet corn DG versus a control diet (corn-soybean meal-based) resulted in a 13.6% increase in efficiency of energy-corrected milk production. The forage component of these diets contained ~63% corn silage and 37% alfalfa hay and resulted in a total dietary CP content of 21% and 22% elevation of serum urea levels. So, long-term considerations when feeding high levels of corn DG need to be: 1) proper ratio of forage sources to reduce dietary CP, and 2) supplemental sources of lysine if corn silage comprises the majority of the forage. It appears that total CP, and possibly lipid, in the diet will set upper limits on the amount of DG that can be incorporated into the ration, but 20 to 30% is feasible if the ration is properly formulated. Logical possibilities exist to combine DG and CGF to capitalize on the unique attributes of both coproducts (digestible NDF from CGF and RUP plus lipid from DG) to create products that would allow higher levels of inclusion in the diet and increase efficiency of milk production. In addition, there is evidence that the lipid in corn DG is effective at increasing the unsaturated to saturated fatty acid ratio in milk fat (Schingoethe et al., 1999).

Two major questions concerning use of DG by dairy cows are: 1) is there a difference between wet and dry DG, and 2) does source of grain for the fermentation impact the nutritive value of the DG. One study (Al-Suwaiegh et al., 1999) has compared wet versus dry DG from the fermentation of either 100% corn or 100% sorghum. All the diets contained 50% of a 1:1 mixture of alfalfa and corn silages and 15% DG. Chemical composition of the corn and sorghum DG were similar. Efficiency of FCM production was similar for cows fed either corn or sorghum DG in the wet or dry form (Table 8). Since efficiency was the same, whether wet or dry, the form of the DG is primarily a function of what works best for the farm given the feed storage and handling capabilities. The production of 4% FCM tended to be reduced when cows were fed DG from sorghum versus corn. The impact of grain source on the quality of DG and its effect on long-term milk production is unknown. Because we know that wet and dry DG are similar, a study needs to be conducted that compares either wet or dry DG fed continuously during early lactation.

Feeding DG and CGF to Dairy Cows: Bottom Line

Unquestionably, DG and CGF are excellent sources of digestible NDF, RUP, and lipid for dairy cattle diets. Particularly for CGF, much more (at least 2x) can be incorporated into diets than has been previously recommended. We need to consider the nutrient profile of these coproducts, and supplement to correct any nutrient deficiencies, either to the diet or by creatively combining various milling coproducts. In addition, we need to manipulate the physical as well as the chemical properties of the forage component of the diet to maximize the use of these coproducts. There is tremendous potential to combine corn milling coproducts that will allow maximal replacement of forage and concentrate. This approach will likely become more important as more ethanol plants are built over the next several years. The traditional paradigm in feeding dairy cattle has been to maximize the amount of forage in the diet which necessitates an exquisite focus on forage quality. However, when high quality forage is expensive or in limited supply, or in areas where coproducts are abundant, the paradigm needs to shift to maximizing use of the byproduct and ensuring that the forage meets the minimal requirements for physically effective NDF. Both DG and CGF products should be effective at providing a consistent quality, highly digestible diet for lactating dairy cows.

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Table 1. Energy Value of Wet vs Dry Distillers Grains

	Control	Wet	Low ^a	Medium ^a	High ^a
Daily feed, lb	24.2 ^{bc}	23.5 ^b	25.3 ^c	25.0 ^c	25.9 ^c
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 (ave.)	
Distillers vs corn		53.8		29.8	

^aLevel of ADIN, 9.7, 17.5 and 28.8%.

^{b,c,d}Means in same row with different superscripts differ ($P < 0.05$).

Table 2. Effect of Wet Distillers Grains Level on Finishing Performance of Yearlings and Calves

Item	DG level, % of diet DM ^a			
	0	5.2	12.6	40.0
Daily feed, lb				
Yearlings ^b	25.21	24.64	24.05	21.30
Calves ^b	18.52	19.23	18.55	17.40
Daily gain, lb				
Yearlings ^c	3.61	3.76	3.85	3.85
Calves ^b	2.86	3.06	3.08	3.21
Feed/gain ^d				
Yearlings ^e	6.94	6.62	6.33	5.78
Calves ^b	6.45	6.33	6.10	5.65

^aWet grains:thin stillage (fed ratio), yearlings = 1.67:1, calves = 1.81:1, DM basis.

^bByproduct level, linear ($P < 0.01$).

^cByproduct level, linear ($P < 0.10$); quadratic ($P < 0.10$).

^dFeed/gain analyzed as gain/feed. Feed/gain is reciprocal of gain/feed.

^eByproduct level, linear ($P < 0.10$).

Table 3. Influence of Level in Diet on Value of Wet Distillers Grains Plus Solubles in Feedlot Diets

Experiment	Wet DG level in diet dry matter		
	0	12.6 - 28%	30 - 50%
Trenkle, 1997a	.154 ^a	.183 (20) ^b 194% ^c	.176 (40) ^b 137% ^c
Trenkle, 1997a	.154		.176 (40) 136%
Trenkle, 1997b	.164	.207 (16) 126%	.168 (40) 102%
Trenkle, 1997b	.164	.171 (28) 114%	
Firkins et al., 1985	.155	.156 (25) 101%	.171 (50) 121%
Larson et al., 1993	.144	.158 (12.6) 177%	.173 (40) 150%
Larson et al., 1993	.155	.164 (12.6) 164%	.177 (40) 135%
Ham et al., 1994	.133		.158 (40) 147%
Fanning et al., 1999	.154		.172 (30) 147%
Means		152% (17.4)	136% (40)
Value 17.4 to 40			124%

^aFeed efficiency.

^bLevel in diet dry matter.

^cValue relative to corn.

Table 4. Energy Value of WCGF-A^a for Beef Finishing Cattle

Reference	Amount in diet, % of DM	Number of replications	Relative feed:gain ^b
Bierman (1995)	41.5	4	1.04
Ham et al. (1995); Trial 1	35.0	4	1.06
	70.0	4	1.06
Ham et al. (1995); Trial 2	17.5	4	1.06
	35.0	4	.97
	52.5	4	1.01
	70.0	4	.97
	87.5	4	1.01
Krehbiel et al. (1995)	35.0	2 ^c	.96
Lodge et al. (1997b)	40.0	2 ^c	1.00
McCoy et al. (1998); Trial 1	45.0	12	.98
McCoy et al. (1998); Trial 2	45.0	16	.99
Average, all levels	47.6	---	1.00
Average, 20 to 60% of diet DM	43.0	---	.997

^aWCGF-A = wet corn gluten feed, 40% DM content.

^bCalculated as feed/gain of control diet divided by feed/gain of treatment diet.

^cIndividually fed cattle trial. Treatment assigned two pen replications for calculation purposes.

Table 5. Energy Value of WCGF-B^a for Beef Finishing Cattle

Reference	Amount in diet, % of DM	Number of replications	Relative feed:gain ^b
Richards et al. (1996)	44.0	4	.89
	42.4	4	.91
	86.6	4	.91
Scott et al. (1997a)	10.4	4	1.02
	20.8	4	.99
	38.2	4	.97
Scott et al. (1997b)	30.0	2 ^c	.90
	60.0	2 ^c	.92
Herold et al. (1998)	22.5	4	.99
Richards et al. (1998)	25.0	8	.97
	50.0	4	.96
Average, all levels	37.3	---	.951
Average, 20 to 60% of diet DM	34.8	---	.949

^aWCGF-B = wet corn gluten feed, 60% DM content.

^bCalculated as feed/gain of control diet divided by feed/gain of treatment diet.

^cIndividually fed cattle trial. Treatment assigned two pen replications for calculation purposes.

Table 6. Ruminant passage and digestion of wet corn gluten feed (CGF).

Item	CGF	CGF + Hay
Ingredients, % of DM		
Alfalfa silage	39.8	19.9
Alfalfa hay	—	18.8
Wet CGF	24.4	24.4
Concentrate mix	35.8	36.9
% Particles \geq 9.5 mm screen	7.3	11.6
NDF intake, % of BW	1.4	1.4
Ruminal mat consistency, ascension rate, cm/sec	0.26 ^a	0.19 ^b
Passage rate of CGF, %/h	6.40 ^a	4.20 ^b
Apparent extent of ruminal NDF digestion, %	32.4 ^b	44.8 ^a
Rumination, min/kg NDF intake	46.5 ^b	59.2 ^a
4% Fat-corrected milk, kg/d	27.9	29.4

^{ab}Means within row with unlike superscript differ ($P < 0.10$).

Table 7. Performance of dairy cows fed 40% wet corn milling feed product (CMP) from day 1 to 63 of lactation.

Item	0% CMP	40% CMP
DMI, % of BW	4.27 ^a	4.06 ^b
NDF intake, % of BW	1.16 ^b	1.40 ^a
4% FCM, kg/d	38.5 ^b	44.6 ^a
FCM/DMI, kg/kg	1.47 ^b	1.79 ^a
Body condition score	2.93	3.00

^{ab}Means within row with unlike superscripts differ ($P < 0.05$).

Table 8. Wet versus dry distillers grains (DG) from corn or sorghum fed at 15% of ration DM.

Item	Corn DG		Sorghum DG	
	Dry	Wet	Dry	Wet
DMI, % of BW	3.9	4.0	4.1	4.0
4% FCM, kg/d	33.3	33.0	31.9	31.3
FCM/DMI, kg/kg	1.3	1.3	1.3	1.2
Milk fat, %	3.7	3.6	3.5	3.5
Milk protein, %	3.4	3.3	3.2	3.2

The Advantages of Using Corn Distillers Dried Grains with Solubles in Dairy Beef Diets

An Economical Addition to Dairy Beef Diets:

- **Dry distillers grains with solubles is an excellent feed for growing Holstein steers**

Recent research results from Iowa State University have shown that 10, 20 or 40% of the ration dry matter as dry distillers grains with solubles could be fed to growing Holstein steers from 425 to 700 lbs without affecting feed intake or gain. Feeding wet distillers grains with solubles tended to decrease feed intake of the growing steers, but improved feed conversion. Feed cost of gain was reduced 6% when corn was priced at \$2.25/bu and dry distillers grains at \$85/ton. At the same prices, feeding wet distillers grains reduced cost of gain 13%.

- **Wet or dry distillers grains can be fed to growing and finishing Holstein steers**

During the 299-day feeding trial, feeding dry distillers grains at 10, 20 or 40% of ration dry matter did not affect feedlot performance or cost of gain. Steers fed 10% wet distillers grains were 4% more efficient and had 5% lower feed cost of gain. Feeding 40% of ration dry matter as wet distillers grains reduced feed intake and rate of gain with similar feed conversion and cost of gain.

- **Feeding distillers grains to growing and finishing Holstein steers can increase profits**

With corn prices at \$2.25/bu, there is profit from feeding 10, 20 or 40% distillers grains to growing Holstein steers if the price of distillers grains is less than \$100/ton (\$33/ton for wet distillers grains with 30% dry matter). When price of distillers grains is low compared with corn, there are greater profits from feeding higher levels. During the growing and finishing period with corn at \$2.25/bu, the price of dry distillers grains had to be less than \$85/ton to profitably include it in the ration. Feeding 10 or 20% wet distillers grains to growing and finishing Holstein steers continued to be profitable with the price of the wet grains at \$33/ton.

- **Feeding wet or dry distillers grains does not affect carcass value**

Feeding 10, 20 or 40% dry distillers grains or 10 and 20% wet distillers grains did not affect carcass weight, marbling, or yield grades. Steers fed 40% wet distillers grains had lighter carcasses but similar marbling and yield grades. Carcass value based on grade and yield or a marketing grid with premiums or discounts for quality and yield grades was not affected by feeding wet or dry distillers grains.

- **Keys to feeding distillers grains to Holstein steers**

- Make changes in the ration to account for the nutrients supplied by distillers grains, namely protein and phosphorus.
- Maintain adequate quantities of effective fiber in the rations containing distillers grains.
- Keep the supply of wet distillers grains fresh.
- Feed the steers to similar final weight as those not fed distillers grains.

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OPTIMIZING THE USE OF DISTILLER GRAIN FOR DAIRY-BEEF PRODUCTION

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SUMMARY

Optimizing the use of distiller grain (**DG**) is becoming increasingly important as ethanol production increases. Dairy-beef production is a system that has the potential to use large amounts of DG. Three-hundred and twenty Holstein steers (420.7 \pm 71.5 lbs initial wt.) were fed finishing diets at the University of Illinois Beef Research Unit. Forty pens were each randomly assigned to ten treatments with eight calves per pen. Ten dietary treatments of various DG levels were randomly assigned to 4 different pens. The calves were fed ad libitum and the cattle were weighed in 28-day intervals. After 112 days, both treatments 7 and 8 along with 9 and 10 were switched to represent the change from 20% to 37.5% and from 37.5% to 20% for both wet distiller grain (**WDG**) and dry distiller grain (**DDG**) (DM basis). Implants were administered twice during the course of the trial. Fecal samples were collected on a per pen basis, sub sampled, and then analyzed for nitrogen (**N**), phosphorus (**P**), and sulfur (**S**). Cattle were then weighed at 270 d and sent to Packerland (Green Bay, WI) to be harvested. Effects of dietary treatment were analyzed using the GLM procedure of SAS. Orthogonal contrasts were used for the control versus DG diets, DDG versus WDG, and diet change from 20 to 37.5% DG versus 37.5 to 20% DG (represented in treatments 7 through 10). Linear and quadratic contrasts were also used for the level of DDG and WDG.

Performance values for average daily gain (**ADG**), dry matter intake (**DMI**), and feed efficiency expressed in feed:gain (**F:G**) were evaluated for the growing period (112 d) and for the entire trial (270 d). Steers fed all treatments performed well and the use of DG showed the potential to improve profitability. Steers had a significant linear decrease in ADG with an increasing level of WDG diets ($P=.0202$) and steers which shifted from high DG to (37.5%) low DG (20%) had significantly lower ADG than steers switched from low DG (20%) to high DG (37.5%) ($P=.0035$). There was a significant quadratic effect on DMI with increasing WDG ($P<.0001$). Steers fed 25% WDG ate more DM than those fed 0% or 50% WDG. There was a linear increase in F:G as the level of DDG increased ($P=.0266$). Steers had a quadratic response in F:G with WDG levels ($P=.0296$). Steers fed 50% WDG were the most efficient (5.68 F:G). WDG diets were significantly more efficient when contrasted against DDG diets ($P=.0009$). There was a linear increase in both P and S levels in the feces with increasing DDG ($P<.0001$, $<.0001$) and a quadratic effect for WDG treatments ($P=.0403$, 0356). When harvested, steers fed DG had a higher dressing percent (**DP**) than control ($P=.03$). The most profitable diets were determined by the relative price of corn and DG. When DDG was priced at \$110/ton and WDG \$100 with \$2.50/bushel corn, low levels (12.5-25%) tended to be most profitable. When DDG were priced at \$90/ton and WDG at \$80/ton with \$2.50/bushel corn, the 25-37.5% diets tended to be most profitable.

INTRODUCTION

Corn distiller grain (**DG**) is a by-product of ethanol production. During alcohol production, starch is removed from the grain and converted to alcohol and carbon dioxide. As a result of the starch removal, the remaining nutrients in the grain is concentrated approximately threefold (Spiehs et al. 2002).

The demand for ethanol is increasing. This trend will result in an abundance of byproducts, like DG that are potential alternatives to corn (Lodge et al. 1997). Many are projecting a threefold increase of DG production within the next decade. Maximizing the value of DG will benefit both the ethanol industry and cattle producers alike. Dairy-beef producers have a plethora of protein and energy sources available to incorporate in their diets, and DG should be a competitive nutrient source.

There has been extensive research completed at the University of Illinois on the nutritional value of wet (**WDG**) and dry (**DDG**) distillers grains (Firkins et al. 1984 and Firkins et al. 1985) and on the nutritional requirements of dairy-beef steers (Hussein and Berger, 1995). Feeding DG in dairy-beef production can be valuable because of the higher protein requirement of the light calves. Research trials conducted at Illinois (Firkins et al. 1984), Nebraska (DeHaan et al. 1982), and Iowa State (Trenkel et al. 1981) demonstrated that DG protein has more than twice the bypass value (undegraded intake protein) compared to soybean meal (**SBM**).

The treatments, as shown in Table 1, were based on previous research with beef steers. Treatments 1 through 4 were selected based on a 1985 study by Firkins and co-workers where finishing steers fed 25 or 50% WDG gained faster and more efficiently than control steers receiving an 87% concentrate diet. When the energy value was expressed relative to corn, the 25 and 50% WDG had values of 103 and 122%, respectively. In addition, a 1986 Nebraska summary (Aines et al. 1986) of five different trials demonstrated that DG average 109% the energy of corn for finishing beef steers. By feeding a combination of DG and urea (Treatment 2), the diet should be equal to SBM by meeting the protein requirements of the growing dairy-beef steer. This combination of urea and DG will be much cheaper per unit of crude protein (**CP**) compared to SBM.

Depending on the protein concentration of the basal ingredients, the 25% DDG diet (Treatment 3) will meet and slightly exceed the protein requirements of growing steers. The high-energy value of the distillers, however, may cause the economics to favor feeding extra protein. This level of distillers may also reduce the risk of subclinical acidosis without reducing intake, which is especially important for dairy-beef steers that are often on high-energy diets for around 300 days.

The 50% DDG diet (Treatment 4) was selected since it serves as both a protein and energy source for dairy-beef steers. In a study conducted by Farlin (1981), diets as high as 64% WDG on a dry-matter (**DM**) basis were fed to finishing beef steers. Even though the dry matter intakes (**DMI**) were reduced by 11%, gains were similar and feed efficiency, expressed in feed:gain ratio (**F:G**) was improved 10% compared to control diet. University of Illinois research with early-weaned beef steers entering the feedlot at 300-350 lbs suggest that energy intake early in the feeding program can have a great effect on the marbling level at slaughter. Increasing the energy density of the diet by feeding high levels of DDG may stimulate marbling deposition earlier in the feeding period resulting in a higher quality grade (**QG**) (Wertz et al. 2001).

Treatments 3 through 6 compared the relative value of WDG and DDG at 25 or 50% of the diet for dairy-beef steers which are important for two reasons. First, it is cheaper and more energy efficient to produce WDG than DDG. Alcohol producers can then sell WDG for slightly less than DDG on an equal DM basis and still generate the same net revenue from the byproduct stream. At the same time, WDG diets may reduce DMI in cattle if the total moisture level is too high. Farlin (1981) demonstrated that including 64% WDG (DM basis) reduced DMI 11%. With young calves the DM level in the diet may have greater effects on intake than with the yearling steers in the Farlin trial. By including the WDG and DDG at two levels, we can answer the question whether DDG is more valuable than WDG at higher inclusion rates. Previous research shows that both WDG and DDG have similar nutritional value when fed at low levels in the diet (Firkins et al. 1984). Additionally, these comparisons are important in that transporting the water in WDG is expensive. For some plants having both DDG and WDG available is the best alternative. WDG could be used by local beef and dairy producers, while those further from the source may find the DDG to be more economical.

MATERIALS AND METHODS

Three-hundred and fifty Holstein steer calves were purchased and sent to the Beef Research Unit at the University of Illinois in August 2002. The steers were immediately put on a pelleted grain mix and long-hay diet, ear-tagged, dewormed, and vaccinated according to their available records. The steers were gradually adjusted to an 85% concentrate-15% corn silage diet by replacing the corn silage with whole corn. The diets were balanced to meet or exceed the 1996 NRC Nutrient Requirements of Beef Cattle. The calves were vaccinated against infectious bovine rhinotracheitis (**IBR**), parainfluenza, clostridia, malignant edema, *Haemophilus somnus*, and *Pasteurella*. The steers were weighed on September 4, 2002 preliminarily and checked for illnesses. Those suffering from shipping fever or pinkeye were treated accordingly.

The steers were weighed on September 18 and 19th on two consecutive days. The two initial weights were averaged to use as a starting weight (420.7 ± 71.5 lbs). Electronic Identification (E-IDs) tags were inserted in all steers. Thirty calves were culled based on health, performance, and weight to create the most uniform set to start the trial. Forty pens were randomly assigned to ten treatments with eight calves per pen. The building has an open front, south exposure, with concrete fence-line feed bunks and the pens (12 X 40 feet) were bedded with wood chips. Electric-heated waters were available in each pen and the area was cleaned on a regular basis. The management and health procedures were approved by the University of Illinois Department of Animal Resources.

Ten dietary treatments that were randomly assigned to 40 different pens. The treatments are based on University of Illinois research and are as described in Table 1. Three different supplements (Table 2) were formulated to provide mineral vitamins and feed additives.

The WDG and DDG grains were provided by Archer Daniels Midland (**ADM**) from their Peoria, Illinois plant. A sample of each dietary treatment along with both the WDG and DDG were sent to a commercial laboratory for analysis.

The cattle were weighed at 28-day intervals. At 56 days, the cattle had their horns blunted with a Barnes dehorner and were implanted with Component E-S Steer Implants from VetLife with Tylan

(progesterone USP 200mg and estradiol benzoate 20mg with 29mg tylosin tartate for a local antibacterial). Cattle health was monitored on a daily basis and animals were treated accordingly. Three steers were removed from trial due to injury or chronic pneumonia. Also, orts were weighed back on a regular basis and subtracted from the amount fed.

After 112 days, both treatments 7 and 8 along with 9 and 10 were switched according to protocol at approximately 750 lbs. This diet change represents the change from 20% to 37.5% and from 37.5% to 20% for both WDG and DDG. In March, the steers received Ralgro-Magnum® implants (Schering-Plough Animal Health located in Union, NJ; dosage is 72mg).

In April, pens were allowed to accumulate manure for 19 to 24 d. Fecal samples were collected on a per pen basis and sub sampled. Chemical analysis was completed at a commercial laboratory for nitrogen (N), phosphorus (P), and sulfur (S).

Cattle were weighed at 270 d and subsequently sent to Packerland (Green Bay, WI) to be harvested. The carcass data collected included hot carcass weight (HCW), ribeye area (REA) between the 12th and 13th rib via chromatography paper, backfat (BF) measured opposite of the loin, marbling scores (MS), and liver abscess scores (LA) were noted.

Statistical Analysis. Effects of dietary treatment were analyzed using the general linear model (GLM) procedure of SAS (1996, SAS Inst., Inc., Cary, NC) for a randomized complete block design. Pen was used as the experimental unit for performance parameters. Individual animal was used as the experimental unit for carcass data. Orthogonal contrasts were used for the control versus DG diets, DDG versus WDG, and diet change from 20 to 37.5% DG versus 37.5 to 20% DG (Treatments 7 through 10). Linear and quadratic contrasts were also used for the level of DDG and WDG.

RESULTS

Performance values for ADG, DMI, and F:G for steers during the growing period (112 d) are given in Table 3. There was a significant linear decrease ($P=.0021$) in ADG among the diets with increasing WDG in the diet (Treatments 5, 6, and 9). There were several significant differences found in DMI. A linear increase in DMI occurred with increasing DDG ($P=.0106$). Likewise, a linear decrease was observed with increasing WDG ($P=.0254$). Finally, the contrast of WDG vs. DDG diets was found to be significant ($P=.0002$); steers consuming DDG having higher DMI. Additionally, there was a linear increase in F:G among increasing DDG level in the diets (Treatments 1, 2, 3, 4, and 7) ($P=.0096$). F:G was significantly more efficient for WDG diets when contrasted to DDG diets ($P=.0369$).

Feedlot performance figures for the entire trial (270 d) based on carcass weight are given in Table 4. There was a significant linear decrease in ADG with increasing WDG levels ($P=.0202$). Steers that were switched from high DG (37.5%) to low DG (20%) (Treatments 7 and 9) versus treatments that change from low DG (20%) to high DG (37.5%) (Treatments 8 and 10) had significantly lower ADG ($P=.0035$). There was a significant quadratic effect on DMI with increasing WDG ($P<.0001$) caused by an increase between control and 25% WDG and decrease at 50% WDG (Figure 1). F:G increased linearly as DDG increased in the diets ($P=.0266$). There was a significant quadratic effect of WDG levels on F:G ($P=.0296$), shown in Figure 2, with no change in F:G from control to 25% WDG

(Treatment 5) and increase in efficiency (decrease in F:G) with 50% WDG (Treatment 6). WDG diets were significantly more efficient when contrasted against DDG diets ($P=.0009$).

Fecal samples were analyzed so that N, P, and S collected on a lbs/hd per d basis could be calculated (Table 5). There were no significant differences among the diets for N composition. However, there was a linear increase in P level with increasing DDG ($P<.0001$). In addition, there was a quadratic affect with P level among increasing WDG in diets ($P=.0403$) with a decrease from 25% WDG to 37.5% WDG and then increase in P level with 50% WDG diet (Figure 3). Manure P levels, were significantly lower for steers fed WDG than DDG diets ($P=.0008$). Manure S levels were increased by feeding DG (Treatments 1 vs. 2-10) ($P=.0026$). Additionally, there was a linear increase in S level due to increasing DDG level ($P<.0001$).

In general, carcass composition was not affected by diet (Table 6). There were significant increases in dressing percent (**DP**) with increasing levels of DG ($P=.03$). A quadratic effect on DP with DDG level ($P=.0079$) was found with an increase from control to 12.5% and decrease in DP at the 50% DDG level. There was a similar quadratic WDG response ($P=.0031$), with the highest DP at 37.5% WDG and decrease at 50% WDG. The quadratic contrasts for DP are shown in Figure 4. Also, with HCW, there was a significant quadratic affect with increasing WDG level ($P=.0095$) with a decrease at 50% WDG. There were no significant differences among MS, LEA, or YG ($P>.05$). Here again, there was a quadratic affect on BF due to increasing levels of WDG ($P=.0360$), with a linear increase from 25-37.5% WDG and decrease to 50% WDG (Figure 5).

As part of the economic evaluation, profits per head were calculated at four different price intervals: \$110/ton DDG and \$100/ton WDG; \$90/ton DDG and \$80/ton WDG at either \$2.50 or \$2.00 per bushel corn. These values are reported in Table 7 and 8, respectfully. As shown in Figure 6 (\$110/ton DDG and \$100/ton WDG with \$2.50/bushel corn), there were quadratic effects with both DDG and WDG level in profits per head with a linear increase from 25-37.5% DG and then decrease with 50% DDG and WDG, respectfully ($P=.0216$, $.0206$). When the profits were calculated at \$90/ton DDG and \$80/ton WDG there were more significant differences (Table 7). First, there was a significant increase in net profit per head with the DG diets vs. control ($P=.0084$). Second, there was a significant quadratic affect on profit with increasing DDG level ($P=.0336$) and a decrease at 50% DDG as shown in Figure 7. Additionally for the \$90/ton DDG and \$80/ton WDG cost analysis, diets consisting of WDG were significantly more profitable than DDG diets ($P=.0336$). There were no statistically significant differences in profitability with diets switching from 37.5-20% DG or 20-37.5% at 750 lbs (Treatments 7 through 10).

Profits calculated with similar DDG and WDG prices but with \$2.00/bushel corn had similar results (Table 8). When figured with \$110/ton DDG and \$100/ton WDG, there was a significant linear decrease in profit with increasing DDG level in the diet ($P=.0093$). As shown in Figure 8 (\$110/ton DDG and \$100/ton WDG with \$2.00/bushel corn), there were quadratic effects with both DDG and WDG level in profits per head with a linear increase from 25-37.5% DG and then decrease with 50% DDG and WDG, respectfully ($P=.0262$, $.0446$). When the profits were calculated at \$90/ton DDG and \$80/ton WDG, there were similar quadratic effects as shown in Figure 9 ($P=.0134$, $.0134$).

DISCUSSION

There was a quadratic effect of WDG ($P=.0017$) on DMI which dropped at the 50% WDG level (Treatment 6). Significant differences in DMI among the DDG and WDG diets are as shown in Table 4. The DDG diets possess higher means indicating that perhaps the WDG were less palatable due to the high moisture level in diet. Next, there is a linear increase in ADG with increasing WDG (Treatments 1, 5, and 6) as shown in Table 4 ($P=.0202$). Additionally, cattle fed lower levels of protein during the growing phase and then switched at 750 lbs. to higher levels (20-37.5% vs. 37.5-20%) had slightly higher ADG ($P=.0035$). This may result from reduce sub-clinical acidosis. There was also a linear increase in F:G with increasing level of DDG in diets ($P=.0266$). This is in contrast to previous trials where DDG had more energy than corn. There was quadratic affect on F:G in WDG diets indicating that there was an increase from control to 25% WDG and then decrease in F:G when evaluated at 50% (Figure 2). Feed efficiency was poorer for steers fed the DDG compared to the WDG. This has been reported in previous studies and probably results from the drying process slowing fiber digestion.

During the finishing period, fecal samples were evaluated for their nutrient profile (Table 5). There were no significant differences among N level ($P >.05$). When comparing the control diet to the DG diets (Treatments 2-10), there was a significantly higher level of S. Among increasing DDG diets, there was a linear increase in both P and S excretion ($P<.0001$) on a lbs/ d per head basis. In contrast, the WDG diets had a quadratic affect (Figure 4) in that the 50% WDG diet had decreased P and S concentrations in the feces compared to feces from steers on the 25% WDG diet. There is no clear explanation for this difference. Also, with P only, there were higher fecal levels with DDG diets than WDG ($P=.0008$). Cattle feeders need to adjust their manure application rates to reflect the high P concentration in the feces from steers fed high levels of DG.

There were few statistically significant differences among the carcass composition characteristics demonstrated in Table 6. These data are important because cattle feeders selling on a grid can be assured that DG additions will not affect carcass values.

In studying the profitability on a dollars/head basis, values were calculated with both \$2.00 and \$2.50/bushel corn for DG purchase prices of \$110 DDG and \$100 WDG; \$90 DDG and \$80 WDG. Profits were calculated with corn priced at \$2.50 per bushel as that represented our average corn price delivered to the bunk during this trial. With the more expensive DG price, the least profitable diet on a net per head basis was Treatment 4 (50% DDG) with \$8.13 as shown on Table 7. There was a quadratic affect with both DDG and WDG ($P=.0216, .0206$) and demonstrated in Figure 6. This indicates that there was a decrease in net profit with 50% DDG and WDG. With the \$90 DDG, this quadratic affect was also noted for both DDG and WDG ($P=.0336, .0153$). Currently DG are available at cheaper prices than these in some localities, which would favor feeding the DG at the higher levels. There were no differences in profitability for high to low DG level (37.5-20%) vs. low to high DG level (20-37.5%).

Similar calculations were performed for corn at \$2.00 per bushel. With both price intervals, the least profitable diet on a net per head basis was also Treatment 4 (50% DDG) with profits of \$24.29 and \$49.95, respectfully as shown on Table 8. When DG was purchased at \$110/ton DDG and \$100/ton WDG, there was a linear decrease with increasing levels of DDG and WDG ($P=.0093, .0402$). Again

with the more expensive DG, there were also a significant quadratic effect among increasing levels of DDG and WDG with a decrease at 50% DG ($P=.0262, .0446$) and exhibited in Figure 8. Here again, this indicates that there was a decrease in net profit with 50% DDG and WDG. With the \$90/ton DDG and \$80/ton WDG, this quadratic effect was also significant for both DDG and WDG ($P=.0134, .0134$) and is shown in Figure 9. These data suggest that the 50% DG diets would be the most profitable only when DG are available at a price lower than corn on a dollars per ton basis.

IMPLICATIONS

Using recent prices, additions of DDG or WDG at moderate levels (12.5%-37.5%), can improve profitability for a dairy-beef operation. Feeding up to 50% DG, can decrease performance but may be profitable if DG is purchased at a low enough price. There were no differences between switching at 750 lbs from 20 to 37.5% or from 37.5 to 20%. WDG vs. DDG are less palatable, particularly when fed at the high level of 50%. At harvest, there are little differences in overall carcass composition when corn is replaced with DG. This is critical to producers selling cattle on a grid. Additionally, as the level of DG increased so did the level of P and S in the feces. This should be considered in dealing with environmental regulations and manure application rate. Dairy-beef steers should be fed DG at 12.5-37.5% of the diet for optimum performance, carcass composition and profit margins without having high levels of P and S in the feces.

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