What We Know About Feeding Corn DDGS to Swine

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Production, Use, and Nutritional Characteristics of DDGS



What is DDGS?

- By-product of the dry-grind ethanol industry
- Nutrient composition is **different** depending on the process
 - DDGS dry-grind fuel ethanol
 - DDGS whiskey distilleries
 - Corn gluten feed wet mill
 - Corn gluten meal wet mill
 - Brewer's dried grains beer manufacturing
- Nutrient content is different depending on the grain source
 - Corn DDGS Midwestern US
 - Wheat DDGS Canada
 - Sorghum (milo) DDGS Great Plains US
 - Corn-sorghum and corn-wheat blends





Comparison of Nutrient Composition (Dry Matter Basis) of High Quality Corn DDGS to Corn Gluten Feed, Corn Gluten Meal, Corn Germ Meal, and Brewer's Dried Grains

	"New Generation" Corn DDGS (UM)	Corn Gluten Feed (NRC)	Corn Gluten Meal (NRC)	Corn Germ Meal (Feedstuffs)	Brewer's Dried Grains (NRC)
Protein, %	30.6	23.9	66.9	22.2	28.8
Fat, %	10.7	3.3	3.2	1.1	7.9
NDF, %	43.6	37.0	9.7	No data	52.9
DE, kcal/kg	4011	3322	4694	No data	2283
ME, kcal/kg	3827	2894	4256	3222	2130
Lys, %	0.83	0.70	1.13	1.00	1.17
Met, %	0.55	0.39	1.59	0.67	0.49
Thr, %	1.13	0.82	2.31	1.22	1.03
Trp, %	0.24	0.08	0.34	0.22	0.28
Ca, %	0.06	0.24	0.06	0.33	0.35
Available P, %	0.80	0.54	0.08	0.17	0.21

Dry-Grind Average Ethanol Yield Per Bushel of Corn (56 lbs)



- Ethanol 2.8 gallons
- DDGS 18 lbs
- CO₂ 18 lbs



Source: Sean Broderick, Commodity Specialists Company

Estimated DDGS Usage in U.S. Swine Feeds 2001-2006 (Metric Tonnes)





Theoretical Potential of Distiller's By-Product Use in the U.S. Livestock and Poultry Industries (Cooper, 2006)



1000 Metric Tonnes

Species (% of Total)	Maximum Dietary Inclusion Rate, %	50% Market Penetration	75% Market Penetration	100 % Market Penetration
Dairy (10.3)	20	1,887	2,831	3,774
Beef (50.2)	40	9,176	13,764	18,352
Pork (23.7)	20	4,348	6,521	8,695
Poultry (15.7)	10	2,877	4,315	5,754
Total		18,288	27,431	36,575

DDGS Varies in Nutrient Content and Digestibility, Color, and Particle Size Among U.S. Sources



Comparison of Nutrient Composition of Golden DDGS to Other "DDGS Sources" (100% Dry Matter Basis)

	Golden Corn DDGS	"DDGS"	High Fat DDGS	Partial De-germed DDGS	Whiskey DDGS	Pelleted DDGS
Protein, %	31.8	29.3	31.6	30.1	29.9	27.0
Fat, %	11.3	3.5	15.3	8.9	8.8	9.00
Crude fiber, %	6.3	7.9	No data	7.8	10.6	15.10
ADF, %	12.4	11.8	17.9	21.0	20.2	No data
Ash, %	6.9	5.3	4.6	7.3	3.7	4.28
DE, kcal/kg*	4053	3808	No data	3796	No data	No data
ME, kcal/kg*	3781	3577	No data	3560	3789	No data
Lys, %	0.92	0.61	0.90	0.83	0.99	No data
Met, %	0.62	0.54	0.54	0.66	0.61	No data
Thr, %	1.17	1.01	1.04	1.13	1.10	No data
Trp, %	0.25	0.18	0.23	0.25	0.27	No data
Ca, %	0.07	0.12	0.06	0.51	0.04	0.17
P, %	0.77	0.78	0.89	0.68	0.57	0.62

*Calculated energy values for swine

Averages, Coefficients of Variation, and Ranges of Selected Nutrients Among 32 U.S. DDGS Sources (100% Dry Matter Basis)



Nutrient	Average	Range	
Dry matter, %	89.3	87.3 – 92.4	
Crude protein, %	30.9 (4.7)	28.7 – 32.9	
Crude fat, %	10.7 (16.4)	8.8 – 12.4	
Crude fiber, %	7.2 (18.0)	5.4 – 10.4	
Ash, %	6.0 (26.6)	3.0 – 9.8	
Swine ME, kcal/kg	3810 (3.5)	3504 – 4048	
Lysine, %	0.90 (11.4)	0.61 – 1.06	
Phosphorus, %	0.75 (19.4)	0.42 – 0.99	

Standardized Ileal Lysine Digestibility Coefficients Among 10 "Golden" Corn DDGS Sources



DDGS Source

Stein et al. (2005)

Relationship Between Lightness of Color (L*) and Digestible Lysine Content of DDGS



Color parameter L*

Prediction of Digestible Lysine from Optical Density (400 to 700 nm)



Urriola et al. (2007)



Urriola et al. (2007)

Comparison of Phosphorus Level and Relative Availability of DDGS for Swine (88% dry matter basis)

	High Quality	DDGS	Corn
	DDG3	NRC (1998)	NRC (1998)
Total P, %	0.78	0.73	0.25
	Range		
	0.62-0.87		
P Availability, %	90	77	14
	Range		
	88-92		
Available P, %	0.70	0.56	0.03



Variation in Particle Size Among DDGS Samples Representing 25 U.S. Ethanol Plants



Variation in Bulk Density (Lbs/Cubic Ft.) Among DDGS Samples Representing 25 U.S. Ethanol Plants



Economics and Prices

Relative Value of DDGS Differs Depending on Species



Quick Calculation of Feed Cost Savings

Thumb rule:

Additions/1000 lb diet

+ 100 lbs DDGS x _____ \$/lb = \$____ + 1.5 lbs limestone x _____ \$/lb = \$____ TOTAL ADDITIONS (A) \$_____

Subtractions/1000 kg diet

- 88.5 lbs corn x _____ \$/lb = \$____
- 10 lbs SBM (44%) x _____ \$/lb = \$____
- 3 lbs dical. phos. x _____ \$/lb = \$____ TOTAL SUBTRACTIONS (S) \$____

(S – A) = Feed cost savings/ton by adding 10% DDGS to the diet

USDA historical wholesale prices for DDGS (\$/short ton) compared to monthly average closing prices of nearmonth corn and soybean meal futures from the CBT.



Issues/Barriers Limiting DDGS Use in Swine Diets



Current Commercial Dietary DDGS Inclusion Rates and Estimated Usage

- Grower-finisher diets ~85-90%
 - 10-20% dietary inclusion rates
- Sow diets ~5-10%
 - Gestation up to 30% dietary inclusion
 - Lactation 5-10% of the diet
- Late nursery diets < 5%
 - Added at 5-10% of the diet

Maximum Inclusion Rates of High Quality DDGS in Swine Diets

(Based Upon University of Minnesota Performance Trials)

- Nursery pigs (> 15 lbs)
 - Up to 25 %
- Grow-finish pigs
 - Up to 30% (higher levels may reduce pork fat quality)
- Gestating sows
 - Up to 50%
- Lactating sows
 - Up to 30%

Assumptions: no mycotoxins

formulate on a digestible amino acid and available phosphorus basis

DDGS Issues/Challenges

- 1. By-product variability
 - a. nutrient content
 - b. nutrient digestibility
 - c. physical characteristics
- 2. Determining the feeding value of new corn distiller's by-products
- 3. Ability to pellet DDGS diets
- 4. Lack of a quality grading system
 - a. difficult sourcing to obtain desired quality and price
- 5. Lack of standardized testing procedures
- 6. Need for quality management and certification
- 7. Need a high degree of
 - a. research
 - b. education
 - c. technical support
- 8. Risk of mycotoxins
- 9. Presence of antimicrobial residues?



Understanding new distiller's byproducts

Comparison of Nutrient Content of Dakota Gold DDGS with High Protein Dakota Gold and Corn Protein Concentrate (100% DM Basis)





Comparison of Amino Acid Content of Dakota Gold DDGS with High Protein Dakota Gold and Corn Protein Concentrate (100% DM Basis)





Comparison of Mineral Content of Dakota Gold DDGS with High Protein Dakota Gold and Corn Protein Concentrate (100% DM Basis)





Opportunity Costs of Corn By-Products in Swine and Poultry Diets

	DDGS Spec. 1	DDGS Spec. 2	HP DDGS	CPC
Swine	\$80.00	\$78.00	\$51.00	\$61.60

Product Flowability



- Particle size is sometimes too fine
- Difficult and costly to pellet
- Minimal cooling or "curing" time before loading
 - Extensive damage to trucks and rail cars



Some of the Nutrient Variability is Due to the Use of Different Approved Laboratory Testing Procedures





Variability of Moisture Content from One DDGS Source Using Approved AOAC Lab Procedures

	Moisture (%)
Procedure 1	12.69
Procedure 2	10.48
Procedure 3	10.09
Procedure 4	10.64
Procedure 5	13.30
Procedure 6	12.60

Need for Quality Management and Certification



- Paradigm shift is beginning to occur
 - improved DDGS quality and consistency
 - Implementation of DDGS Quality Assurance Programs
 - Many commercial feed mills are ISO 9000:2001 and HAACP Certified
 - EU International Feed Ingredient Standard
 - GMP Certification
 - transparency of information
 - aggressive sampling and nutrient analysis
Lysine Monitoring Big River Resources 1/11/05 – 3/6/06 (100% DM Basis)





Antimicrobial Use In Ethanol Production

- Used to control bacterial (lactobacillus) contamination
- Can increase ethanol yield by as much as 25%
- Which ones are used?
 - Virginiamycin (0.25 to 2.0 ppm)
 - Penicillin (1 g/1000 liters)
 - Unique compared to forms used in animal feeds



Antimicrobials in Ethanol Production

• Virginiamycin

- Is destroyed at temperatures > 93° C
- Dryer temperatures range from 93 to 232° C
- There are no detectable residues in DDGS
- Penicillin
 - Easily inactivated by primary alcohols and some sugars
 - Completely degraded at pH 3 and a temperature of 37° C for 30 minutes
 - There are no residues in DDGS



Mycotoxins



- Risk of mycotoxin contamination in DDGS is low
 - Poor quality corn = poor ethanol yields
 - Corn supplied to ethanol plants is generally produced locally
 - Corn produced in upper Midwest is has a low risk for mycotoxins
 - Most ethanol plants monitor for mycotoxins of incoming corn
- Must use thin layer chromatography (TLC) or HPLC for testing mycotoxins in DDGS
 - ELISA and other methods result in false positives

Other Barriers Limiting DDGS Use in Swine Diets



- Understanding and managing impact on pork fat quality
- Inconsistent feed intake responses with increasing levels of DDGS in the diet
- In vitro procedures to estimate amino acid digestibility among DDGS sources
 - Fast
 - Accurate
 - Inexpensive
- Net energy values of DDGS sources need to be determined

Feeding High Quality DDGS to Weaned Pigs





Effect of DDGS Level on Growth Rate



Means not sharing a common superscript letter are significantly different (P < .05)

Effect of DDGS Level on Average Daily Feed Intake





Effect of DDGS Level on Gain/Feed







Feeding High Quality DDGS to Grower-Finisher Pigs





Study 1 – "Worst Case Scenario"



Materials and Methods



- 240 crossbred pigs (~ 63 lbs initial BW)
 - Pens randomly assigned to 1 of 4 experimental diets
 5-phase feeding program
 - 0, 10, 20, or 30% DDGS diets
 formulated on total lysine basis
 diets contained up to 4% soybean oil
 - 24 pens, 10 pigs/pen, 6 replications/trt

Effect of Dietary DDGS Level on Overall ADG of Grow-Finish Pigs



0 % and 10 % DDGS > 20% and 30% DDGS (P < .10)



Effect of Dietary DDGS Level on Overall ADFI of Grow-Finish Pigs



No significant differences among dietary treatments



Effect of Dietary DDGS Level on Overall G/F of Grow-Finish Pigs







Effect of Dietary DDGS Level on % Carcass Lean





No significant differences among dietary treatments

Effect of Dietary DDGS Level on Carcass Characteristics of Grow-Finish Pigs

	0% DDGS	10% DDGS	20% DDGS	30% DDGS
Slaughter weight, lbs	258	263	249	247
Carcass weight, lbs	189 ^c	191°	180 ^d	178 ^d
Dressing %	73.4 ^c	72.8°	72.1 ^d	71.9 ^d
Fat depth, in.	0.85	0.87	0.84	0.82
Loin depth, in.	2.26 ^{ac}	2.16 ^b	2.19 ^c	2.06 ^d
% Lean	52.6	52.0	52.6	52.5

^{a, b} Means within row with unlike superscripts differ (P < .05).

^{c, d} Means within row with unlike superscripts differ (P < .10).

Muscle Quality Characteristics from Grow-Finish Pigs Fed Diets Containing 0, 10, 20, and 30% DDGS

Trait	0 %	10 %	20 %	30 %	RMSE
L*a	54.3	55.1	55.8	55.5	2.9
Color score ^b	3.2	3.2	3.1	3.1	0.8
Firmness score ^c	2.2	2.0	2.1	2.1	0.5
Marbling score ^d	1.9	1.9	1.7	1.9	0.6
Ultimate pH	5.6	5.6	5.6	5.6	0.2
11-d purge loss, %	2.1 ^f	2.4 ^{fg}	2.8 ^g	2.5 ^{fg}	1.2
24-h drip loss	0.7	0.7	0.7	0.7	0.2
Cooking loss, %	18.7	18.5	18.3	18.8	2.6
Total moisture loss ^e , %	21.4	21.5	21.8	22.1	3.1
Warner-Bratzler sheer force, kg	3.4	3.4	3.3	3.3	0.5

^a 0 = black, 100 = white

^b1=pale pinkish gray/white; 2=grayish pink; 3=reddish pink; 4=dark reddish pink; 5=purplish red; 6=dark purplish red c1 = soft 2 = firm 3 = very firm

^c 1 = soft, 2 = firm, 3 = very firm

^d Visual scale approximates % intramuscular fat content (NPPC, 1999)

^e Total moisture loss = 11-d purge loss + 24-h drip loss + cooking loss



Fat Quality Characteristics of Market Pigs Fed Corn-Soy Diets Containing 0, 10, 20, and 30% DDGS

	0 %	10%	20%	30%
Belly thickness, cm	3.15ª	3.00 ^{a,b}	2.84 ^{a,b}	2.71 ^b
Belly firmness score, degrees	27.3 ª	24.4 ^{a,b}	25.1 ^{a,b}	21.3 ^b
Adjusted belly firmness score, degrees	25.9 ^a	23.8 ^{a,b}	25.4 ^{a,b}	22.4 ^b
lodine number	66.8 ^a	68.6 ^b	70.6 ^c	72.0 ^c

Means within a row lacking common superscripts differ (P < .05).

Study 2 – U of M/Land O' Lakes Field Trial





U of M/Land O' Lakes Pork Fat Quality Field Study (2006)

Facilities

- Two commercial 1000 head finishing barns in southern MN
- Separate sites, two independent producers
- Each barn had 40 pens, double sided curtain
 - buildings with 8' pits
 - pit fans for ventilation
 - weighted baffle ceiling air inlets

• Genetics

- Monsanto Genepacker sows
- Monsanto EB terminal semen



U of M/Land O' Lakes Pork Fat Quality Field Study (2006)

• Nutrition

- Provided by Land O' Lakes
- Producer A fed typical corn-soybean meal diets
- Producer B fed corn-soybean meal diets containing 10% DDGS
- 7-phase mixed sex feeding program
- Last finisher diet contained 4.5g Paylean
- Diets contained similar nutrient levels with and without 10% DDGS
- All diets contained choice white grease as the supplemental fat source (1.25 to 3.75%).

Growth Performance of Grow-Finish Pigs Fed 0 or 10% DDGS Diets (UM/LOL Field Trial)







Measurement	0% DDGS Diets	10% DDGS Diets
Carcass weight, lbs	212	210
Last rib backfat, in.	1.09	1.11
Tenth rib backfat, in.	1.01	0.99
Ham, %	11.74	11.74
Loin, %	7.93	7.91
Belly, %	10.51	10.41
Loin depth, in.	2.72	2.72
Lean %	56.36	56.47

No significant differences in carcass characteristics.

Mid-Belly Fat Quality Characteristics of Grow-Finish Pigs Fed 0 or 10% DDGS Diets (UM/LOL Field Trial)



Measurement	0% DDGS Diets	10% DDGS Diets
Japanese fat color score (1-4)	1.76	1.81
Mean melting point, °C	29.26	28.70
lodine value	66.7 ^a	68.3 ^b
14:0, 16:0, 16:1, 17:0, 17:1, 18:0, %	No differences	No differences
18:1 oleic acid, %	47.39°	45.12 ^d
18:2 linoleic acid, %	11.94°	13.98 ^d
18:3, 18:4, 20:0, 20:1, 20:2, 20:4, %	No differences	No differences
Saturated fatty acids, %	33.99	34.26
Monounsaturated fatty acids, %	51.78°	49.47 ^d
PUFA, %	14.02°	16.11 ^d
Total Omega 3, %	0.98	0.96
Total Omega 6, %	13.02°	15.14 ^d
Omega 6:Omega 3 ratio	13.28°	15.78 ^d

^{a, b} Means within rows with unlike superscripts differ (P < .05).

^{c, d} Means within rows with unlike superscripts differ (P < .0001).

Study 3 – Effect of Formulating G-F Diets Containing Increasing Levels of DDGS on a Digestible Amino Acid Basis on Growth Performance and Pork Quality





Effect of Formulating G-F Diets on a Digestible Amino Acid Basis, with Increasing Levels of DDGS, on Overall Growth Performance

	0% DDGS	10% DDGS	20% DDGS	30% DDGS
Initial wt., lbs	49.7	50.3	49.7	49.7
Final wt., lbs	252	253	251	250
ADG, lbs/d	2.03	2.03	2.03	2.01
ADFI, Ibs/d ^a	5.66	5.62	5.49	5.42
F/G ^a	2.79	2.76	2.71	2.70

^a Linear effect of DDGS level

Data from 64 pens, 16 pens/treatment (Xu et al., 2007)

Adding Increasing Levels of DDGS to G-F Diets Slightly Reduces Carcass Yield



Xu et al. (2007) Linear effect (P < 0.01)



Effects of Dietary DDGS Level on Last Rib Backfat



Xu et al. (2007) 30% DDGS tended to be lower than 0% DDGS (P = 0.09)

Effects of Dietary DDGS Level on % Carcass Lean



Xu et al. (2007) 30% DDGS tended to be higher than 0% DDGS (P = 0.11)



Effects of Increasing Dietary DDGS Level on Loin Characteristics

• No difference in:

- ultimate pH
- subjective color score
- drip loss on day 0, 14, 21, or 28 post-harvest
- lipid oxidation in loins at 28 days of shelf storage
- Loin firmness was linearly reduced
 - Due to reduced marbling
 - Within accepted NPPC quality standards
- Marbling was linearly reduced
 - Due to trend for reduced backfat
 - Within accepted NPPC quality standards
- Pigs fed the 30% DDGS diets had loins that were slightly less red
 - Within accepted NPPC quality standards



Effects of Increasing Dietary DDGS Level on Eating Characteristics of Pork Loins (Consumer Taste Panel)

• No difference in:

- Cooking loss
- Flavor
- Off flavor
- Tenderness
- Juiciness
- Overall eating quality

Adding Increasing Levels of DDGS to G-F Diets Linearly Reduces Belly Firmness



Xu et al. (2007)

Effects of Increasing Dietary DDGS Level on Belly and Backfat Characteristics

- No effect on belly thickness
- No differences in belly fat color
 - Japanese color score
 - Minolta L*, a*, b*
- Backfat was slightly darker (lower L*) for pigs fed the 20% and 30% DDGS diets
- No differences in backfat color
 - Japanese color score
 - Minolta a*, b*



Take Home Messages



- Diets containing 10% DDGS will provide the same ADG as pigs fed typical corn-SBM diets
 - Diets formulated on a total lysine basis
 - Diets formulated on a digestible amino acid basis
- If >10% DDGS is added to G-F diets, diets should be formulated on a digestible amino acid basis to achieve good performance.
- Feed intake may decline with increasing levels of DDGS in the diet
 - Unclear why different studies show different feed intake responses
 - Diets containing >10% DDGS may result in improved feed efficiency

Take Home Messages

- Carcass yield is slightly linearly reduced with increasing dietary DDGS levels
 - No difference in % lean
 - No difference in backfat
 - May be due to increased viscera weight from increased dietary fiber?
- Backfat thickness is unaffected, and may be slightly reduced, with increasing dietary levels of DDGS
- Bellies will be less firm as higher dietary levels of DDGS are fed
- Belly thickness may or may not be affected by increasing dietary DDGS levels
- No concern about reduced shelf life and fat oxidation in loins under typical retail storage conditions for at least 28 days.
- Muscle quality and eating characteristics are generally unaffected by feeding diets containing increasing levels of DDGS
Effect of Feeding Diets Containing DDGS on Feed Intake of Growing Pigs (Published)



No Effect

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Does Feeding DDGS Improve Gut Health of Growing Pigs?











Effect of Dietary Treatment on Lesion Length (21 d Post-Challenge)





^{*} Effect of disease challenge (*P* < .01).



Effect of Dietary Treatment on Lesion Severity (21 d Post-Challenge)



^{*} Effect of disease challenge (*P* < .01).

Effect of Dietary Treatment on Lesion Prevalence (21 d Post-Challenge)





^{*} Effect of disease challenge (*P* < .01).



Feeding High Quality DDGS to Sows





Effect of Feeding a 50% DDGS Diet on Sow Weight Gain During Gestation (Reproductive Cycle 1)





Effect of Feeding 0 or 50% DDGS Gestation Diets and 0 or 20% DDGS Lactation Diets on Pigs Weaned/Litter



^{a,b,x,y} Different superscripts indicate significant difference (P < .10).



Effect of Dietary Treatment Combination on Sow Lactation ADFI



^{a,b,x,y} Different superscripts indicate significant difference (P < .10).



Effects of Feeding Increasing Levels of DDGS to Lactating Sows on Average Daily Feed Intake and Average Pig Weight at Weaning (Song et al., 2006)



Utilized 323 lactating sows (65 sows/dietary treatment)



Diet Composition When 18.8% DDGS and Phytase are Added to a Swine Grower Diet

Ingredient	Corn-SBM-1.5 kg Lysine	18.8% DDGS + Phytase
Corn, kg	798.3	636.3
Soybean meal 44%, kg	176.9	159.4
DDGS, kg	0.0	188
Dicalcium phosphate, kg	11.6	0.0
Limestone, kg	7.2	9.8
Salt, kg	3.0	3.0
L-lysine HCl, kg	1.5	1.5
VTM premix, kg	1.5	1.5
Phytase, 500 FTU/kg	0.0	0.5
TOTAL, kg	1000.0	1000.0

Effect of Feeding Corn-SBM Diets With or Without 20% DDGS or Phytase on Fecal Phosphorus Concentration (%)



a,b Means with different superscripts are significantly different (P < .05).

Effect of Feeding Corn-SBM Diets With or Without 20% DDGS or Phytase on Daily Fecal Phosphorus Excretion (g/d)



a,b,c Means with different superscripts are significantly different (P < .05). x,y Means with different superscripts are significantly different (P < .15).

U of M DDGS Web Site www.ddgs.umn.edu

We have developed a DDGS web site featuring:

* research summaries

- swine, poultry, dairy, & beef
- DDGS quality
- * presentations given
- * links to other DDGS related web sites
- * international audiences
- * nutrient profiles of DDGS sources

