What We Know about Feeding Dried Distillers Grains with Solubles (DDGS) to Swine

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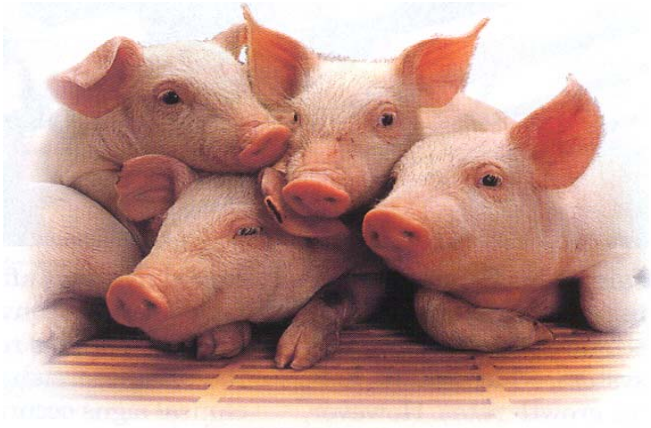
Overview

- U.S. DDGS production and usage levels in pork production
- Nutrient composition and digestibility of DDGS for swine
- DDGS quality issues
- Effects of feeding DDGS diets
  - Weaned pigs
  - Grower-finisher pigs
    - growth performance
    - carcass composition
    - pork fat and lean quality
    - gut health
    - manure management
  - Sows
- Key points



U.S. DDGS Production

- Currently ~ 201 ethanol plants (+12 under construction, 6 in expansion)
  - Industry is operating at 88% of total production capacity
  - Majority are dry-grind vs. wet mill
  - Common sizes
    - 40 to 100 million gallons ethanol produced/yr
  - Plants operate 354 days/yr
  - 100 million gal. plants produce 6,200 tons of DDGS/week
  - Plant storage capacity for DDGS is < 1 wk
- 2009 – 25.5 million metric tonnes
  - 64% dried vs. 36% wet (cattle feed)
  - ~16% fed to swine

Maximum Inclusion Rates of DDGS in Swine Diets

(Based Upon University Trials)

- Nursery pigs
  - Up to 30%
- Grow-finish pigs
  - Up to 30%
- Gestating sows
  - Up to 50%
- Lactating sows
  - Up to 30%

Assumptions: no mycotoxins

formulate on a digestible amino acid and available P basis

Current U.S. Pork Industry Ranges in Dietary DDGS Inclusion Rates and Estimated Usage

- 70- 80% of MN pork producers are using DDGS in their swine diets

- Grower-finisher diets ~ 80-85%
  - 10 - 40% of the diet
  - Save $3 to $10/ton for each 10% DDGS added to the diet
  - Save $3 to $9/market hog for each 10% added to the diet

- Sow diets ~ 10-15%
  - Gestation – 10 - 90% of the diet
  - Lactation – 10 - 30% of the diet

- Late nursery diets < 5%
  - Added at 5 - 30% of the diet

Nutritional Characteristics of DDGS for Swine

- DDGS Metabolizable Energy = corn ME
- Amino acid content and digestibility is variable among sources
  - Total lysine (0.61-1.06% DM basis)
  - Standardized true lysine digestibility (44 - 67%)
- High digestible P
  - Reduce diet inorganic P supplementation
  - May reduce manure P excretion
- Partially replaces some corn, soybean meal, and inorganic phosphate and reduces diet cost

Quick Calculation of Feed Cost Savings

Thumb rule:

Additions/1000 kg diet

+ 100 kg DDGS x _____ $/kg = $_____
+ 1.5 kg limestone x _____ $/kg = $_____
TOTAL ADDITIONS (A) $_____

Subtractions/1000 kg diet

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

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

Nutrient Composition Comparison of Corn, Sorghum, Corn DDGS, and Sorghum DDGS (As-fed Basis)

	Corn	Sorghum	Corn DDGS	Sorghum DDGS
ME, kcal/kg	3,420	3,340	3,507	3,287
Crude protein, %	8.0	9.8	27.5	31.0
Crude fat, %	3.3	2.9	10.2	7.7
NDF, %	7.3	7.3	25.3	34.7
ADF, %	2.4	3.8	9.9	25.3
Ash, %	0.9	0.8	3.8	3.6

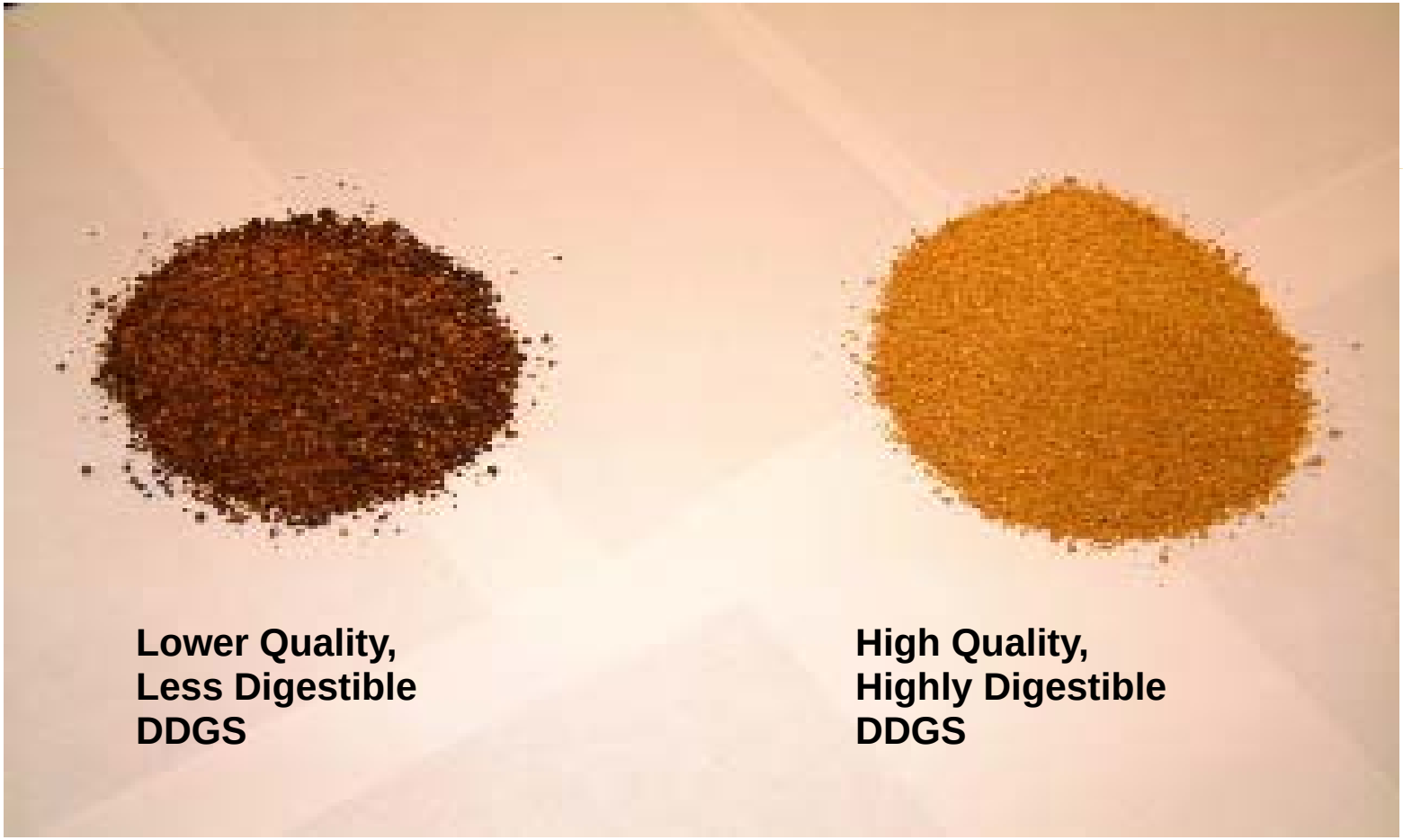
Amino Acid and Mineral Composition Comparison of Corn, Sorghum, Corn DDGS, and Sorghum DDGS (As-fed Basis)

	Corn	Sorghum	Corn DDGS	Sorghum DDGS
Lysine, %	0.24	0.20	0.78	0.68
Methionine, %	0.21	0.18	0.55	0.53
Threonine, %	0.26	0.29	1.06	1.07
Tryptophan, %	0.09	0.07	0.21	0.35
Valine, %	0.38	0.48	1.35	1.65
Isoleucine, %	0.28	0.37	1.01	1.36
Calcium, %	0.01	0.01	0.03	0.03
Phosphorus, %	0.22	0.24	0.61	0.64

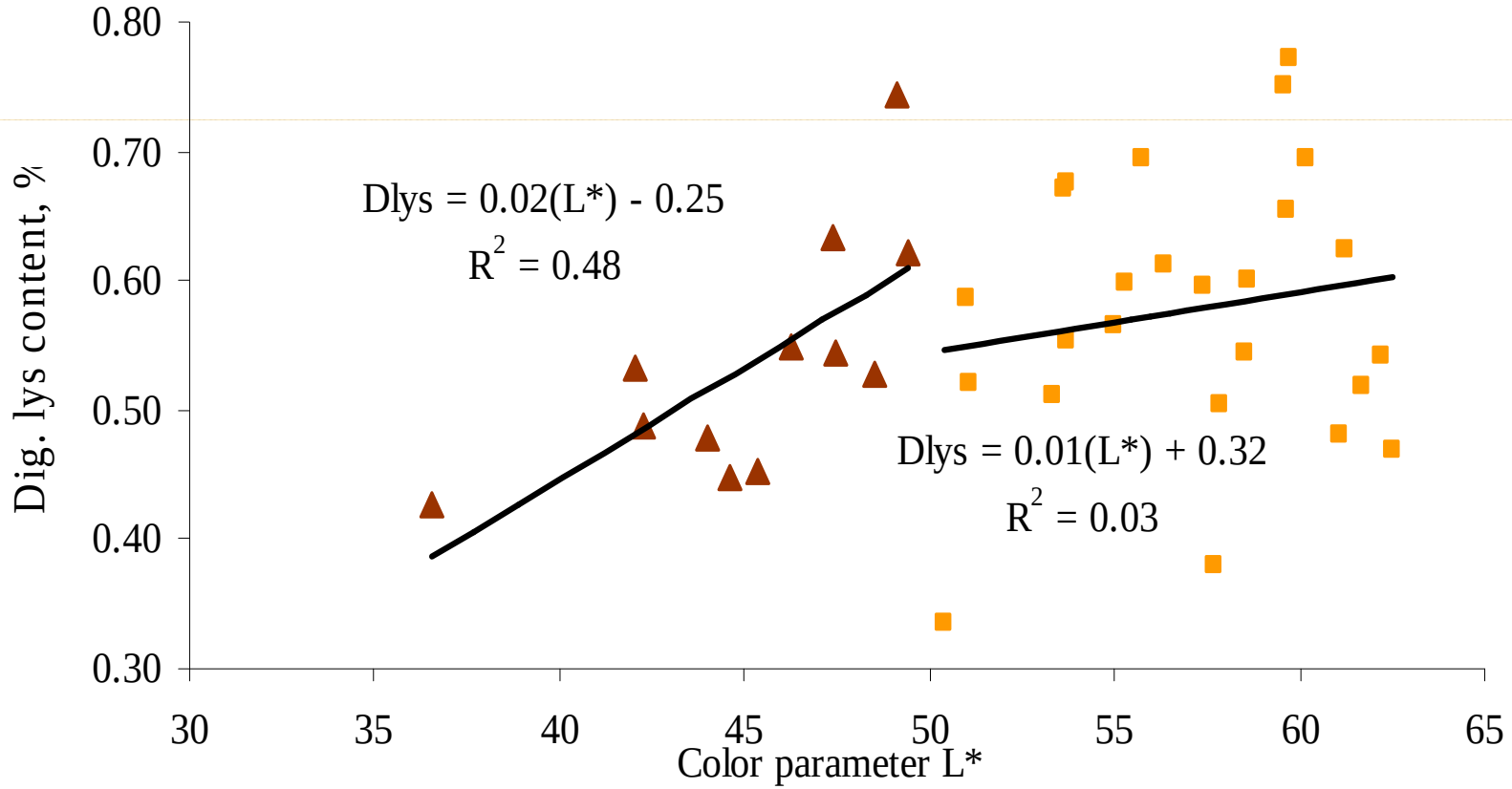
Standardized Ileal Digestibility of Amino Acids in Corn, Sorghum, Corn DDGS, and Sorghum DDGS (As-fed Basis)

	Corn	Sorghum	Corn DDGS	Sorghum DDGS
Lysine, %	72	57	62	62
Methionine, %	85	69	82	75
Threonine, %	74	64	71	68
Tryptophan, %	70	57	70	70
Valine, %	79	64	75	72
Isoleucine, %	81	66	75	73

DDGS Color and Digestibility Varies Among DDGS Sources



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



The Old Evaluation Criteria are Inadequate

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

Nutrient	Average	Range	% Variation
Dry matter, %	89.3	87.3 – 92.4	*5.8*
Crude protein, %	30.9 (4.7)	28.7 – 32.9	*14.6*
Crude fat, %	10.7 (16.4)	8.8 – 12.4	*41 %*
Crude fiber, %	7.2 (18.0)	5.4 – 10.4	*92 %*
Ash, %	6.0 (26.6)	3.0 – 9.8	*226*
Swine ME, kcal/kg	3810 (3.5)	3504 – 4048	*15.5*
Lysine, %	0.90 (11.4)	0.61 – 1.06	*73*
Phosphorus, %	0.75 (19.4)	0.42 – 0.99	*135 %*

New Nutritional "Tools" Are Available to Assess Value and Provide Accurate Nutrient Loading Values Among DDGS Sources

- **Examples:**
  - **Cargill - Reveal®**
  - **Value Added Science and Technology - Illuminate®**

Illuminate Nutrient Loadings

	A	B	C	D	E
ME	3070	3460	2970	3410	3540
Dig. Lys	0.54	0.52	0.54	0.61	0.54
Dig. Met	0.50	0.47	0.49	0.48	0.46
Dig. Thr	0.70	0.68	0.70	0.72	0.68
Dig. Trp	0.16	0.15	0.16	0.16	0.14
Avail. Phos	0.67	0.50	0.62	0.56	0.64
Relative Value	$175	$204	$165	$208	$215

Comparison of Phosphorus Level and Relative Availability of DDGS for Swine (As-fed Basis)

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

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, %	79.8	63.6
Soybean meal 44%, %	17.7	15.9
DDGS, %	0.0	18.8
Dicalcium phosphate, %	1.16	0.0
Limestone, %	0.72	0.98
Salt, %	0.30	0.30
L-lysine HCl, %	0.15	0.15
VTM premix, %	0.15	0.15
Phytase, 500 FTU/kg	0.00	0.05
TOTAL, %	100.0	100.0

DDGS Quality

- Are there concerns about…
  - Mycotoxins?
  - Antimicrobial residues?
  - Need for antioxidants?
  - Flowability?
  - Pelleting?

Presence of Mycotoxins in DDGS Samples from 14 Ethanol Plants in 7 States in the Midwest U.S. (NCERC, 2008)

Mycotoxin	N	Minimum Level	Maximum Level	Average Level	% Samples Above Lowest FDA Level
Aflatoxin, ppb	20	< 1	3.7	0.7	0 %
DON, ppm	20	< 0.1	1.2	0.3	0 %
Fumonisin, ppm	20	< 0.1	8.6	1.9	10 %
T-2 toxin, ppm	20	< 0.1	< 0.1	0.0	NA
Zearalenone, ppm	20	< 0.05	0.14	0.04	NA

Presence of Mycotoxins in DDGS Samples from a Midwestern U.S. Ethanol Plant (2/06 – 11/07)

Mycotoxin	N	Minimum Level	Maximum Level	Average Level	% Samples Above Lowest FDA Level
Aflatoxin, ppb	69	< 1	2.6	0.08	0 %
DON, ppm	69	< 0.1	1.4	0.6	0 %
Fumonisin, ppm	69	0.12	5.9	2.3	3 %
T-2 toxin, ppm	69	< 0.1	< 0.1	0.0	NA
Zearalenone, ppm	69	< 0.05	0.1	0.03	NA

Presence of Mycotoxins in DDGS Samples from 4 Midwestern U.S. Ethanol Plants (2/08 – 7/08)

Mycotoxin	N	Minimum Level	Maximum Level	Average Level	% Samples Above Lowest FDA Level
Aflatoxin, ppb	77	< 1	1.1	0.01	0 %
DON, ppm	77	0.2	1.9	0.5	0 %
Fumonisin, ppm	77	< 0.2	7.2	2.7	10 %
T-2 toxin, ppm	77	Not available	Not available	Not available	NA
Zearalenone, ppm	77	< 0.2	< 0.2	0.0	NA

Antimicrobial Residues?

- Virginiamycin (Lactrol) is the only FDA approved antimicrobial for use in ethanol production
  - FDA issued a letter of no objection 11/16/93
  - Added at rate of 2-6 ppm in the fermentation phase
  - Controls bacterial infections
    - Approved swine feed usage rate for Stafac is 5-100 g/ton of feed
  - Is destroyed by high temperatures (< 93° C during ethanol production
    - Dryer temperatures range from 93 to 232° C

Antibiotic Residues?

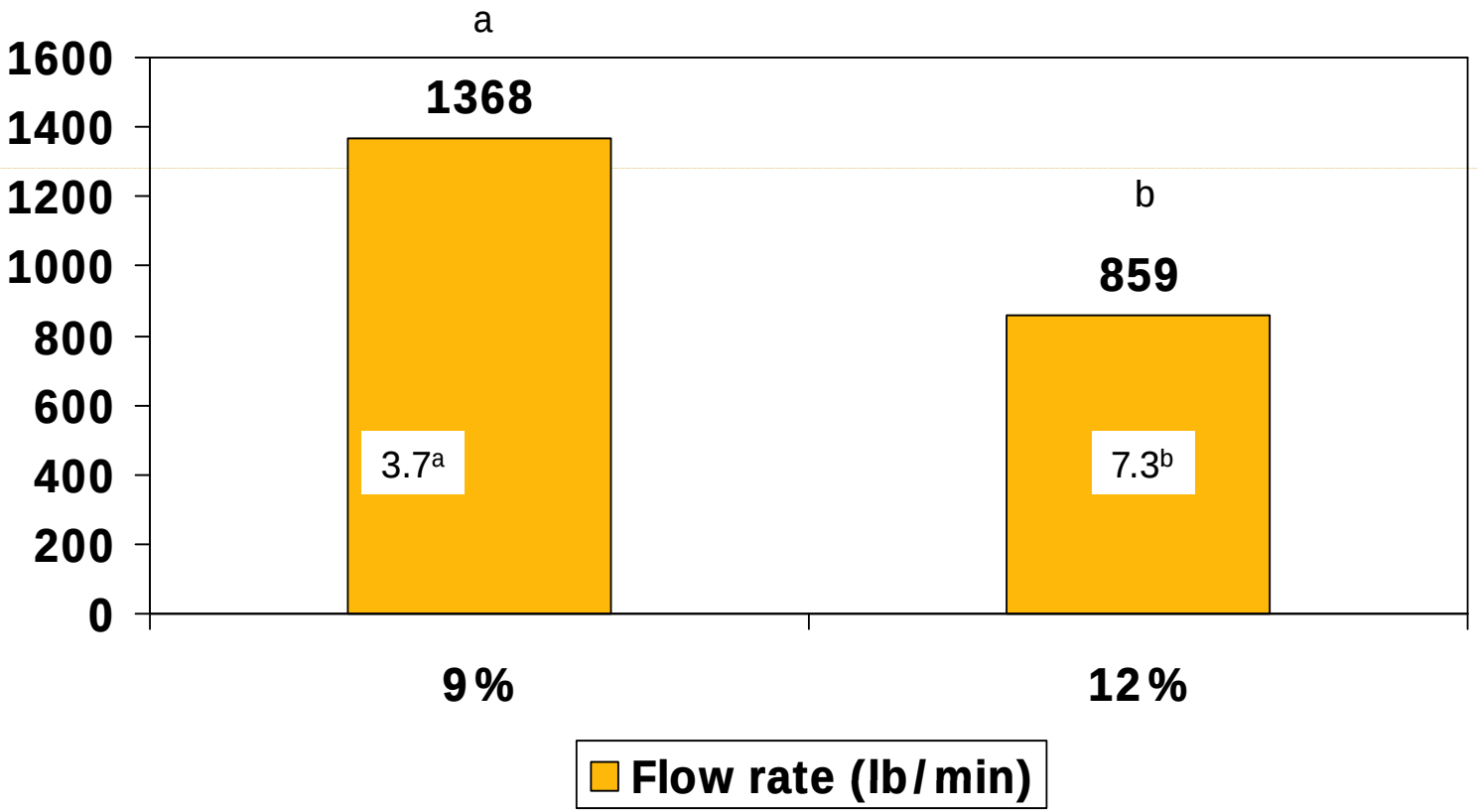
- 2008 FDA multi-state sampling survey
  - antibiotic residues were detected in 24 of 45 samples (53%)
  - 15 of the 45 samples contained residues of virginiamycin (33%)
  - 27 % contained residues of erythromycin
  - 11 % contained residues of tylosin
  - A multi-analyte residue detection method was used by FDA to detect antibiotic residues as low as 0.1 ppm (dry matter basis)

Fat Stability of DDGS in Taiwan

Analysis	Week 1	Week 10
Peroxide value, mEq/kg	0.70	0.60
Free fatty acids, % as oleic	11.2	16.2

Peroxide values < 5 mEq/kg are considered acceptable for fat quality and there is no oxidative rancidity.

Effect of Moisture Treatments on Flow Rate and Discharge Score



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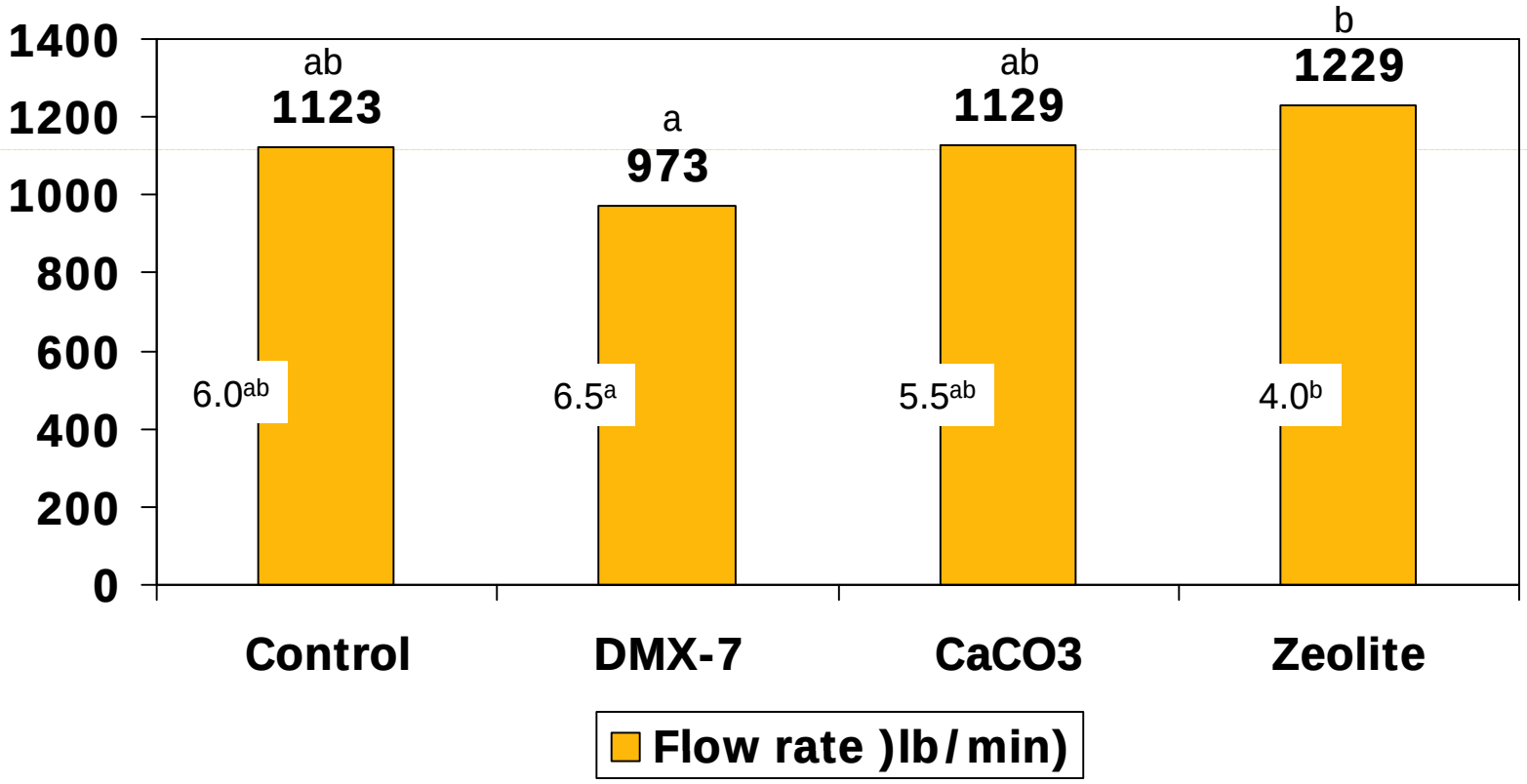
Effect of Adding Flowability Agents on DDGS Flow Rate and Discharge Score



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Feeding High Quality DDGS to Weaned Pigs

Summary of Growth Performance Effects of Feeding Levels up to 30% DDGS in Weanling Pig Diets

Item	N	Response to dietary corn DGS		
		Increased	Reduced	Not changed
ADG	10	0	0	10
ADFI	10	0	2	8
G:F	10	5	0	5

Data calculated from experiments by Whitney and Shurson (2004), Gaines et al. (2006), Linneen et al. (2006), Spencer et al. (2007), Barbosa et al. (2008), and Burkey et al. (2008).

Feeding DDGS to Grower-Finisher Pigs

Summary of Growth Performance Responses from Feeding Levels up to 30% DDGS in Grower-Finisher Diets

Performance Measure	N	Increased	Reduced	Not Changed
ADG	25	1	6	18
ADFI	23	2	6	15
Gain/Feed	25	4	5	16

Effect of Formulating G-F Diets on a Digestible Amino Acid Basis, with Increasing Levels of DDGS, on Overall Growth Performance (Xu et al., 2007)

	0% DDGS	10% DDGS	20% DDGS	30% DDGS
Initial wt., lb	49.6	50.3	49.6	49.6
Final wt., lb	251	254	251	249
ADG, lb/d	2.03	2.03	2.03	2.01
ADFI, lb/d[a]	5.67	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)

Summary of Carcass Characteristic Responses from Feeding Levels up to 30% DDGS in Grower-Finisher Diets

Performance Measure	N	Increased	Reduced	Not Changed
Dressing %	18	0	8	10
Backfat Thickness	15	0	1	14
Loin Depth	14	0	2	12
% Carcass Lean	14	0	1	13

Muscle Quality is Not Affected by Feeding DDGS Diets to Grower-Finisher Pigs

- No effects on muscle:
  - Color
  - Firmness
  - Marbling
  - Ultimate ph
  - Drip loss
  - Cooking loss
  - Tenderness

Summary of Belly Quality Characteristics from Feeding Levels up to 30% DDGS in Grower-Finisher Diets

Performance Measure	N	Increased	Reduced	Not Changed
Belly thickness	4	0	2	2
Belly firmness	3	0	3	0
Iodine value	8	7	0	1

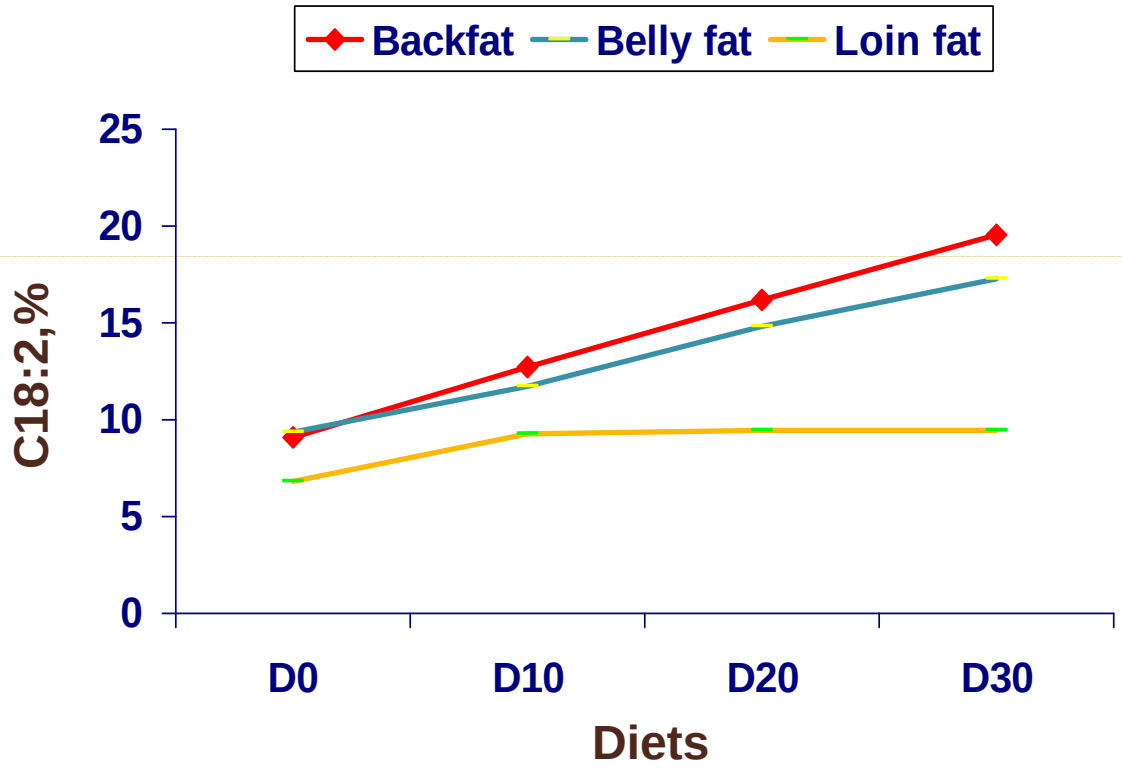
Comparison of Selected Nutrients in Corn DDGS and Corn (As Fed Basis)

Nutrient	Corn DDGS	Corn
Swine ME, kcal/kg	3,507	3,420
Crude fat, %	10.2	3.3
Linoleic acid (C18:2), %	5.32	1.92
Oleic acid (C18:1), %	2.47	0.94

Current Pork Fat Quality Standards

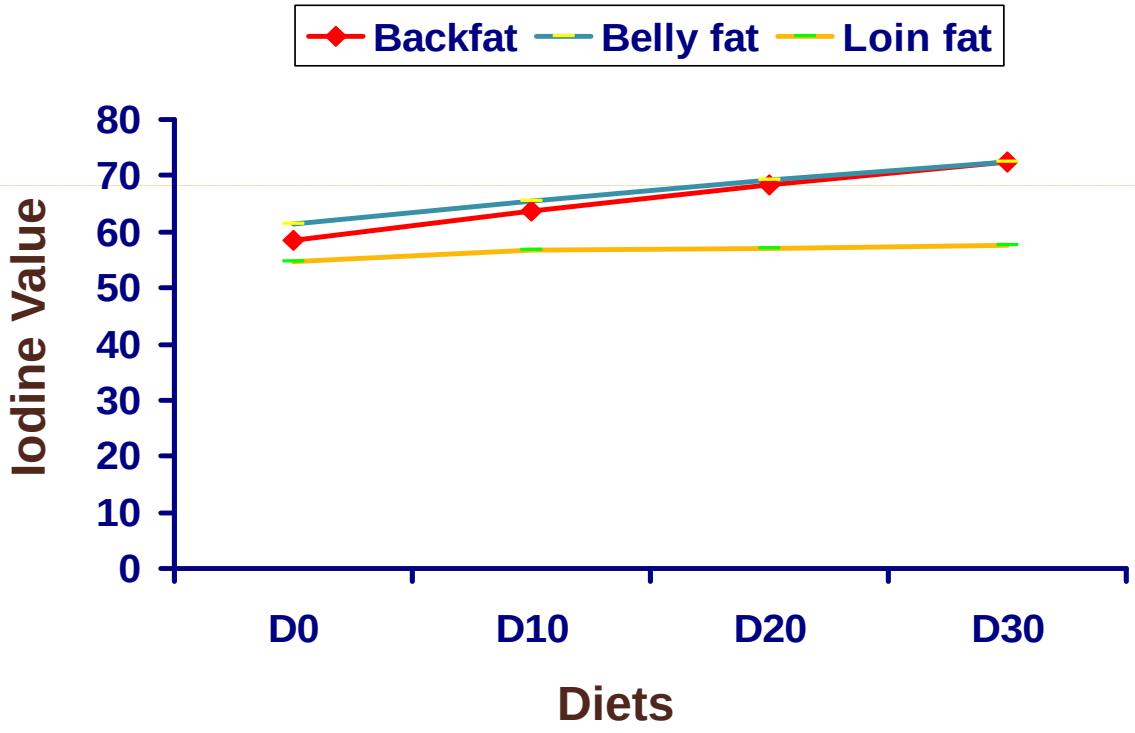
- Based on Iodine Value (IV)
  - ratio of unsaturated:saturated fatty acids
- Maximum IV
  - 70 – Danish Meat Research Institute
  - 72 – National Pork Producers Council
  - 74 – Boyd et al. (1997)
- Various adipose tissue sites are affected differently by dietary fatty acid composition

Effect of Dietary DDGS Level on Linoleic Acid (C18:2) Content of Pork Fat



Linear effect of DDGS level for all fat depot sites (P < 0.01)
Diet × site (P < 0.01)

Effect of Dietary DDGS Level on Iodine Value of Pork Fat



Linear effect of DDGS level for all fat depot sites (P < 0.01)
Diet × site (P < 0.01)

Fat Quality Characteristics of Market Pigs Fed Corn-Soy Diets Containing 0, 10, 20, and 30% DDGS (Whitney et al., 2006)

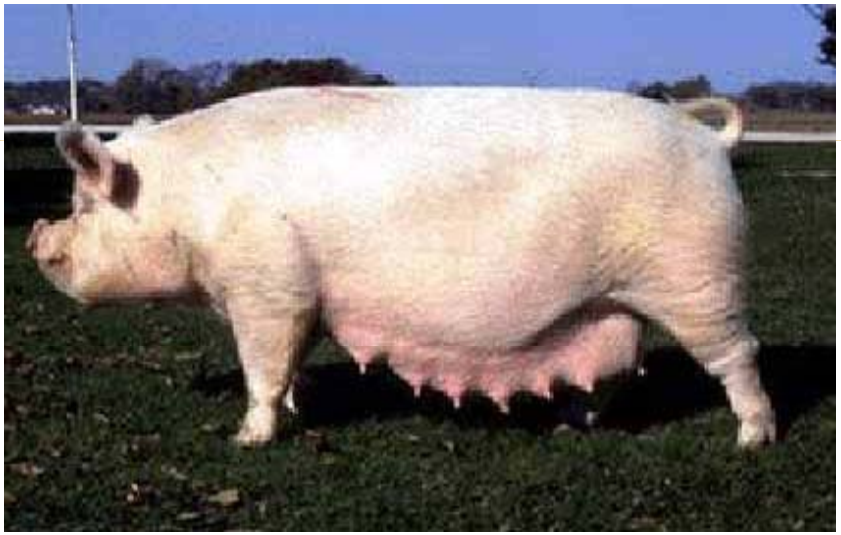
	0 %	10%	20%	30%
Belly thickness, cm	**3.15^{a}**	**3.00^{a,b}**	**2.84^{a,b}**	**2.71^{b}**
Belly firmness score, degrees	**27.3^{a}**	**24.4^{a,b}**	**25.1^{a,b}**	**21.3^{b}**
Adjusted belly firmness score, degrees	**25.9^{a}**	**23.8^{a,b}**	**25.4^{a,b}**	**22.4^{b}**
Iodine number	**66.8^{a}**	**68.6^{b}**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

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

Summary of the Effects of Feeding DDGS Diets on Pork Quality

- **Bellies** will be **less firm**
  - Increased iodine value (linoleic acid content)
- **Bacon** will have an **oily appearance** from pigs fed > 20% DDGS diets
- **Belly thickness** may or may **not** be **affected**
- **Shelf life** and fat oxidation in fresh pork loins is **unaffected** with typical retail storage conditions for 28 days.
- **Muscle quality** is **not affected**
- **Consumer taste** panel acceptability is **unaffected**
  - Cooked pork loin
  - Cooked bacon
- Backfat **iodine value of 70** can be met when feeding **30% DDGS** in growing-finishing and **withdrawing** it **3 wks pre-harvest**

Feeding DDGS to Sows



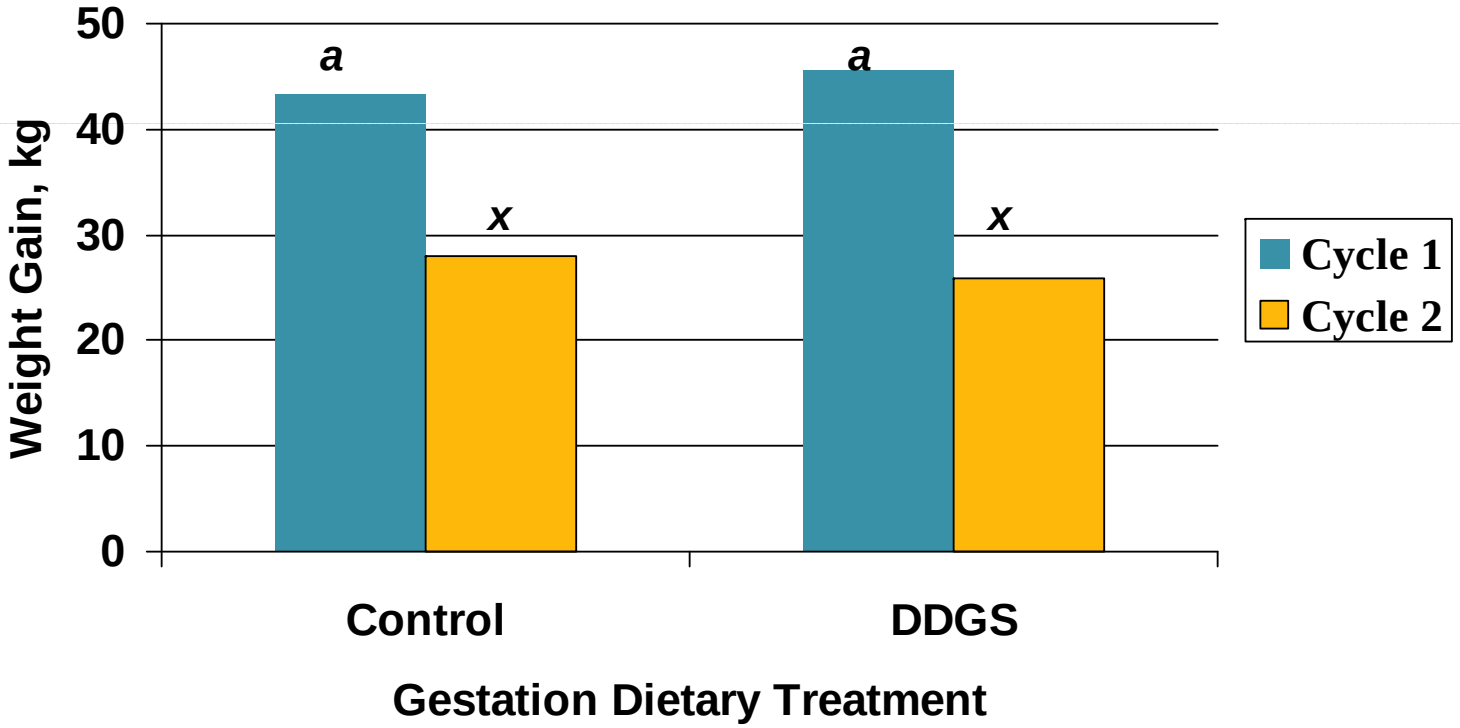
Producer Perceptions and Observations

- Perception
  - DDGS is a risky ingredient because of mycotoxin concerns
    - Has limited DDGS use compared to potential
- Observations
  - Increased lactation feed intake
  - Sows are more content
  - Fewer constipation problems

Previously Published Recommendations for Maximum Use of DDGS in Sow Diets

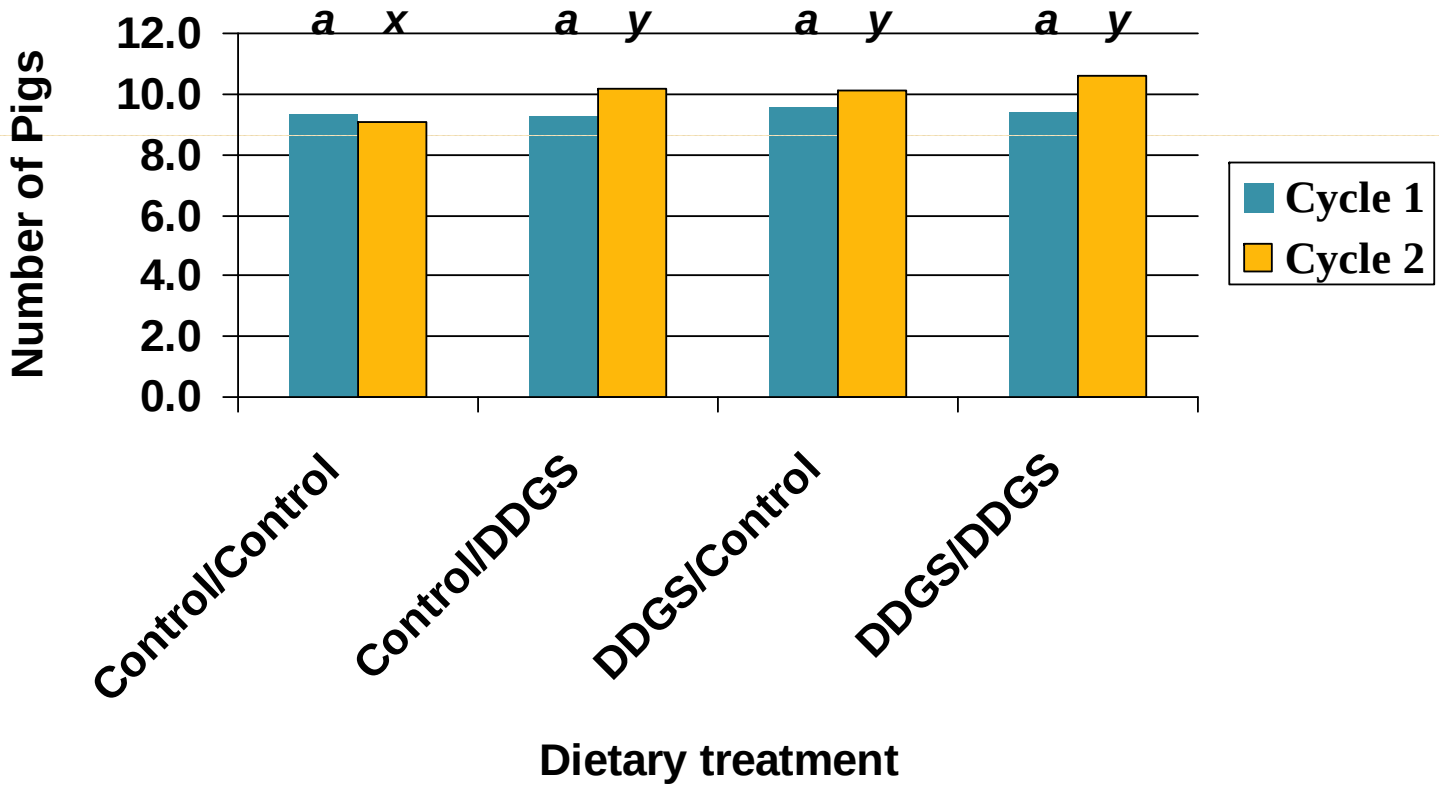
- Feed Co-Products Handbook (1997)
  - up to 50% in gestation diets
  - up to 20% in lactation diets
- Pork Industry Handbook
  - up to 40% in gestation diets
  - up to 10% in lactation diets

Effect of Feeding a 50% DDGS Diet on Sow Weight Gain During Gestation – Wilson et al., 2003



[a,b,x,y] **Different superscripts indicate significant difference (P < .10).**

Effect of Feeding 0 or 50% DDGS Gestation Diets and 0 or 20% DDGS Lactation Diets on Pigs Weaned/Litter – Wilson et al., 2003



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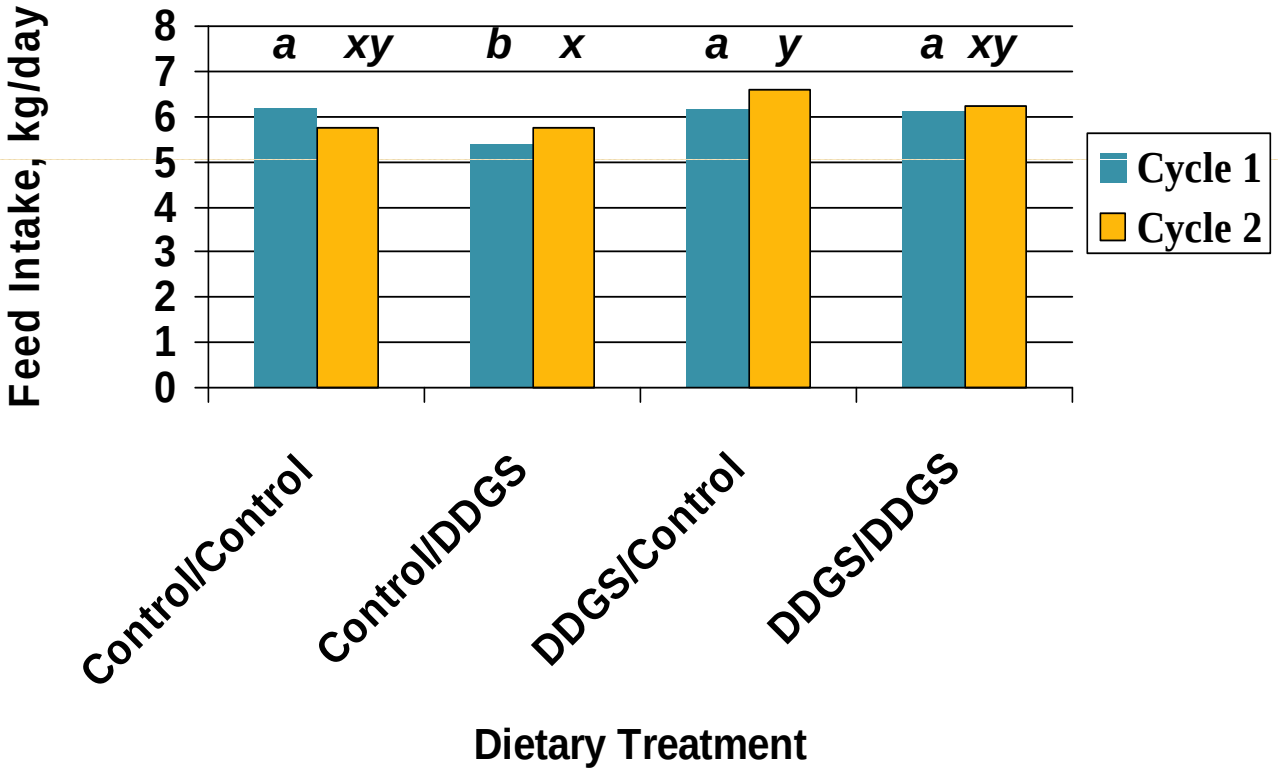
Effect of Dietary Treatment Combination on Sow Lactation ADFI – Wilson et al., 2003



[a,b,x,y] **Different superscripts indicate significant difference (P < .10).**

Effects of Feeding up to 30% DDGS to Lactating Sows - Song et al. (2006)

- 307 mixed parity sows

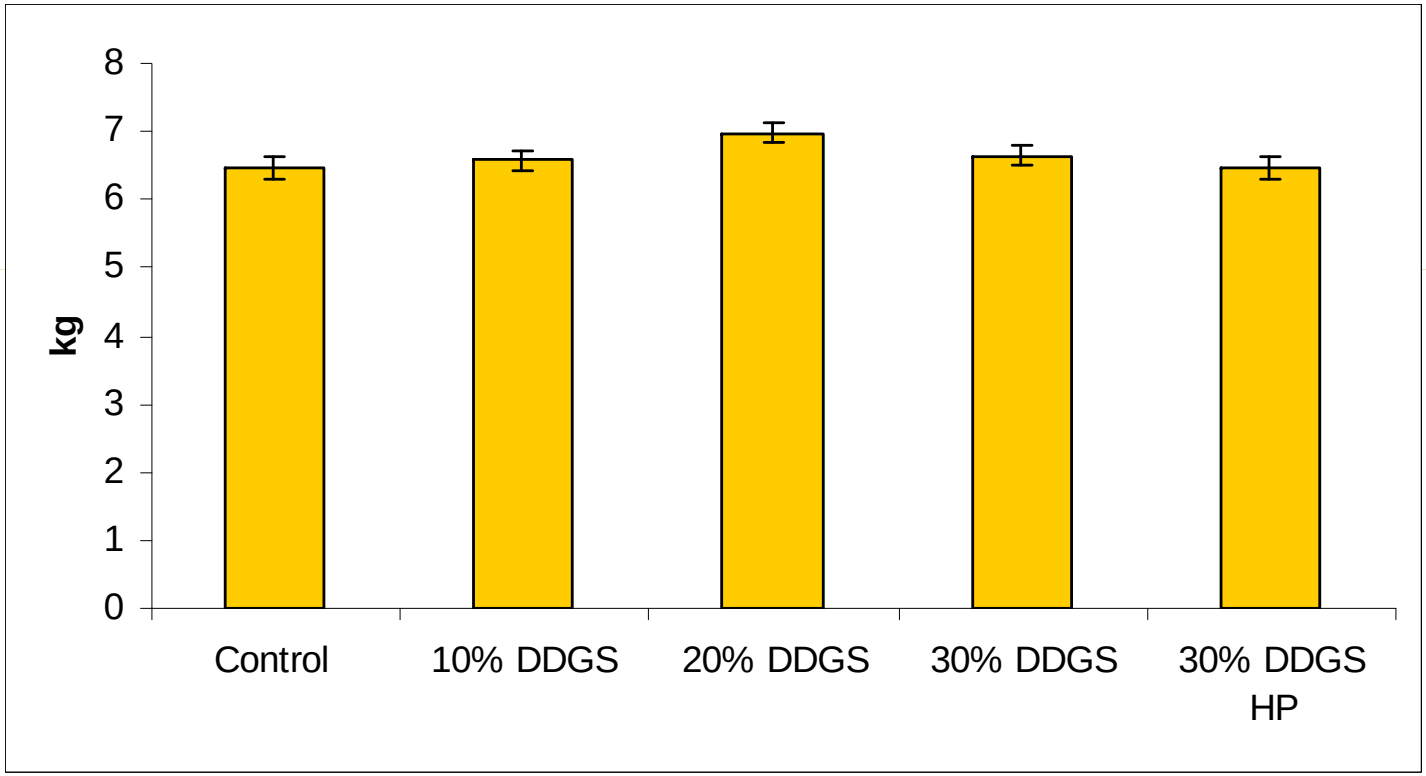
  - Group housed = 147 sows
  - Individual crates = 160 sows

- English Belle, GAP genetics, Winnipeg, MB, Canada
- Average initial weight of about 490 lbs

Group housing

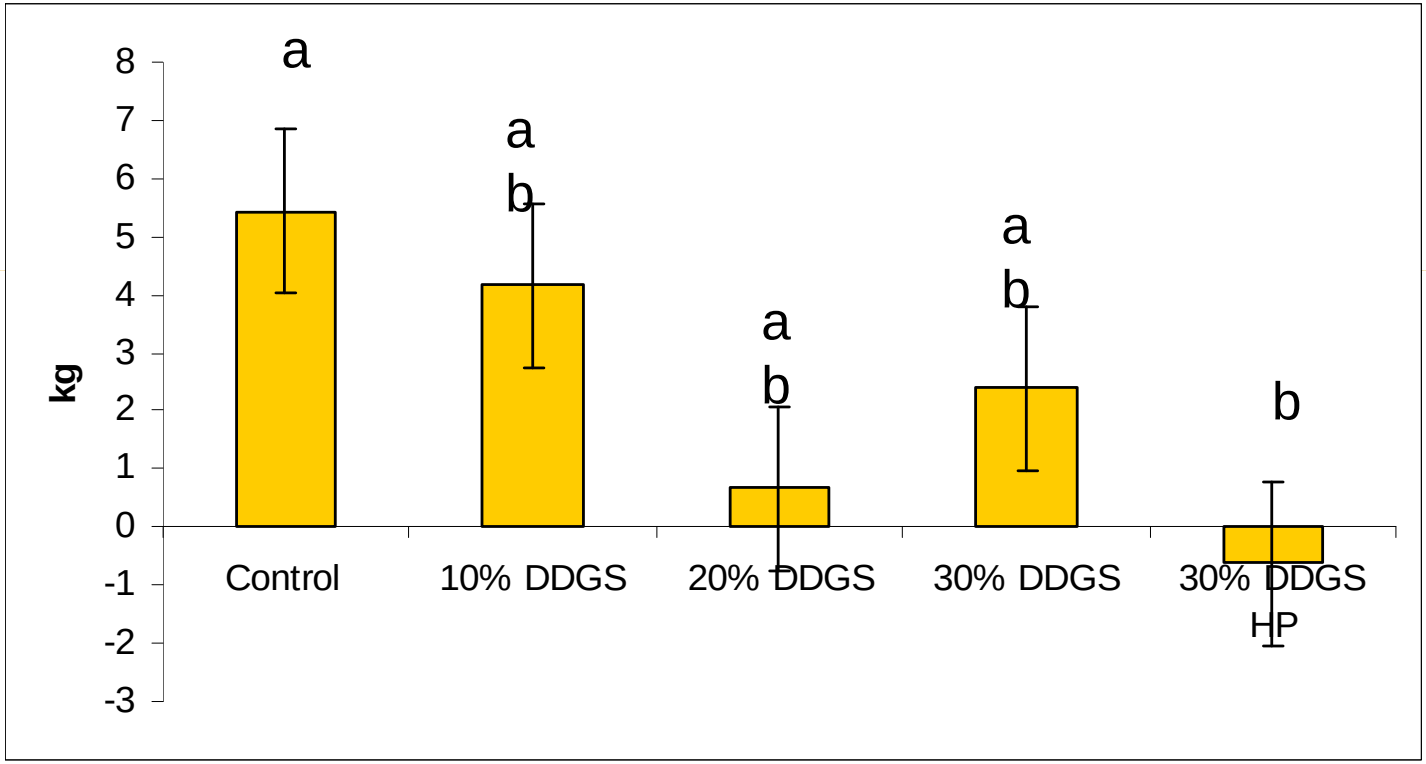
Individual housing

Effect of Increasing Dietary DDGS Level on Sow ADFI in Lactation



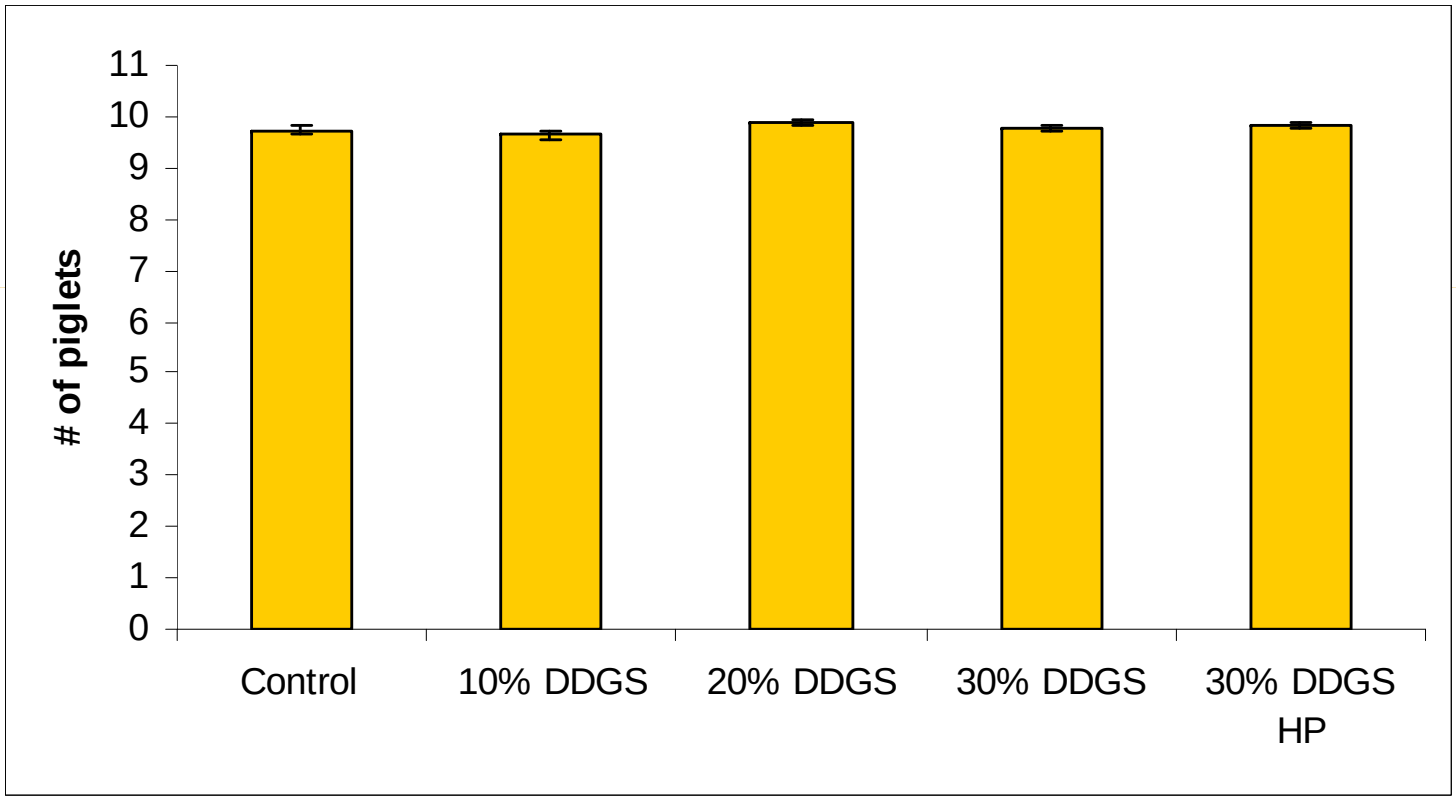
No significant difference (P = 0.10)

Effect of Increasing Dietary DDGS Level on Sow Body Weight Change



[a,b] Means with different superscripts are significantly different ($P < 0.05$)

Effect of Increasing Dietary DDGS Level on Litter Size at Weaning



No significant difference (P = 0.31)

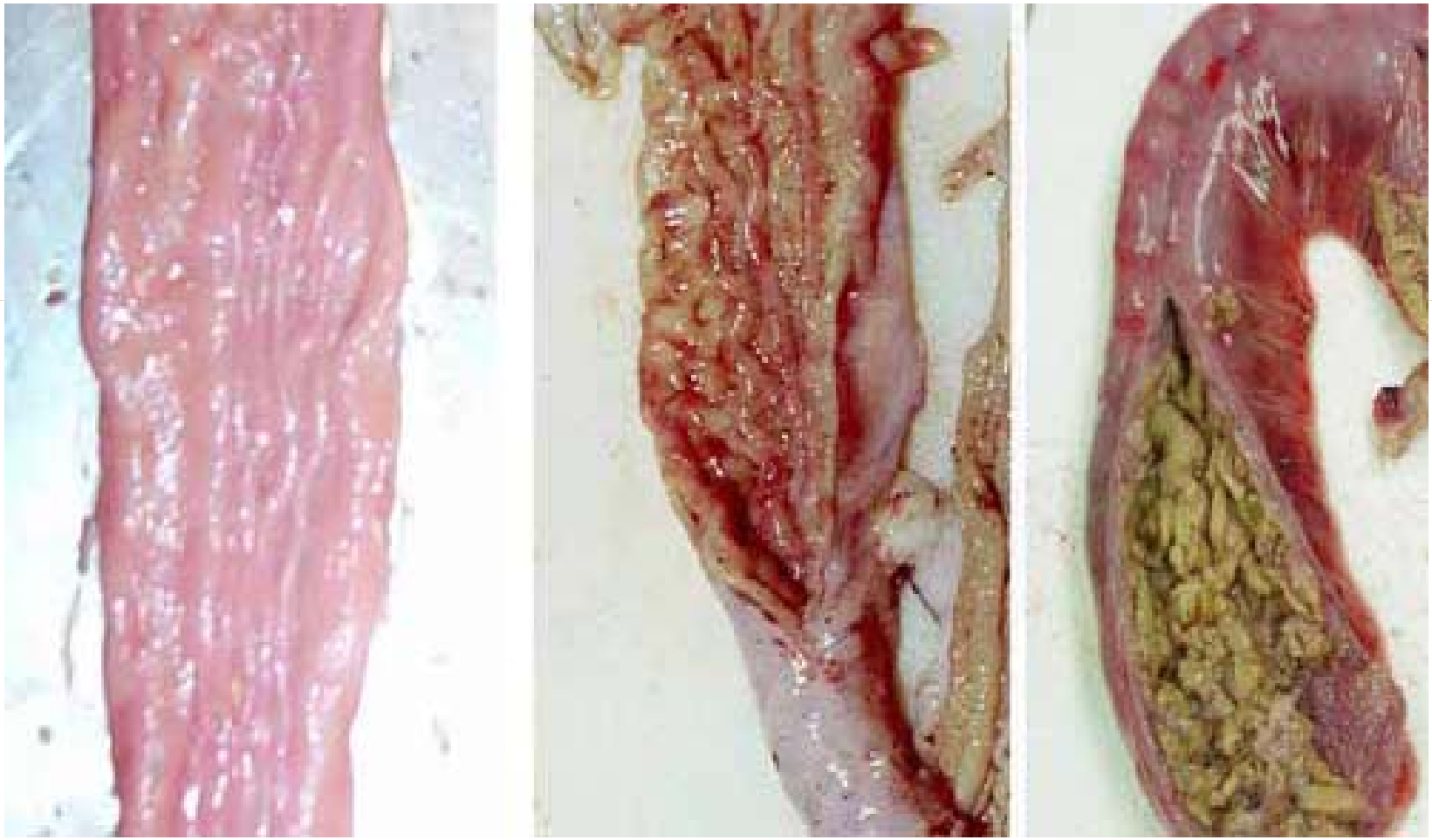
Conclusion

- Inclusion of up to 30% DDGS in sow lactation diets did not affect:
  - Sow and litter performance
  - Digestible and metabolizable energy
  - Nitrogen retention and digestibility
  - Milk nitrogen and fat concentration

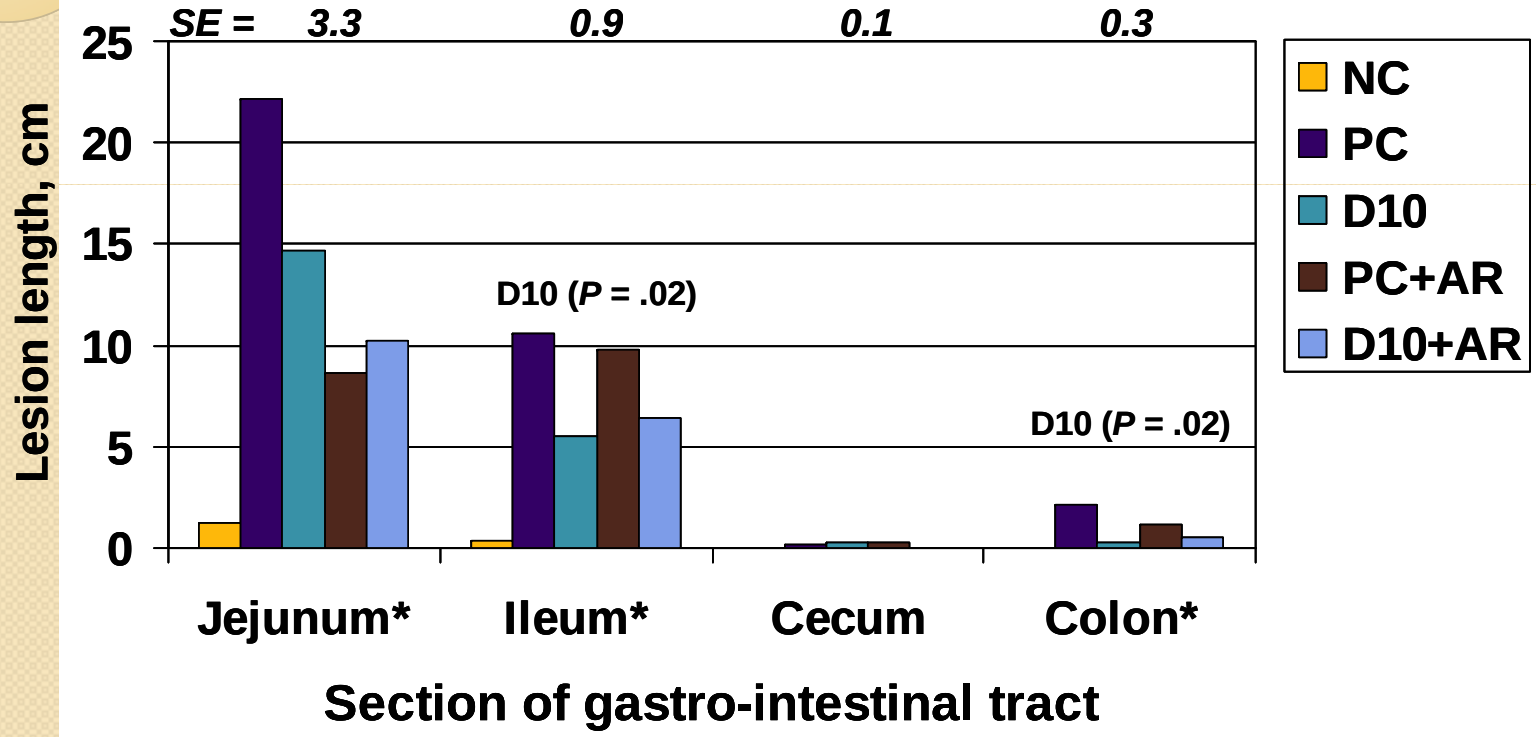
Does Feeding DDGS Improve Gut Health of Growing Pigs?

Healthy

Ileitis

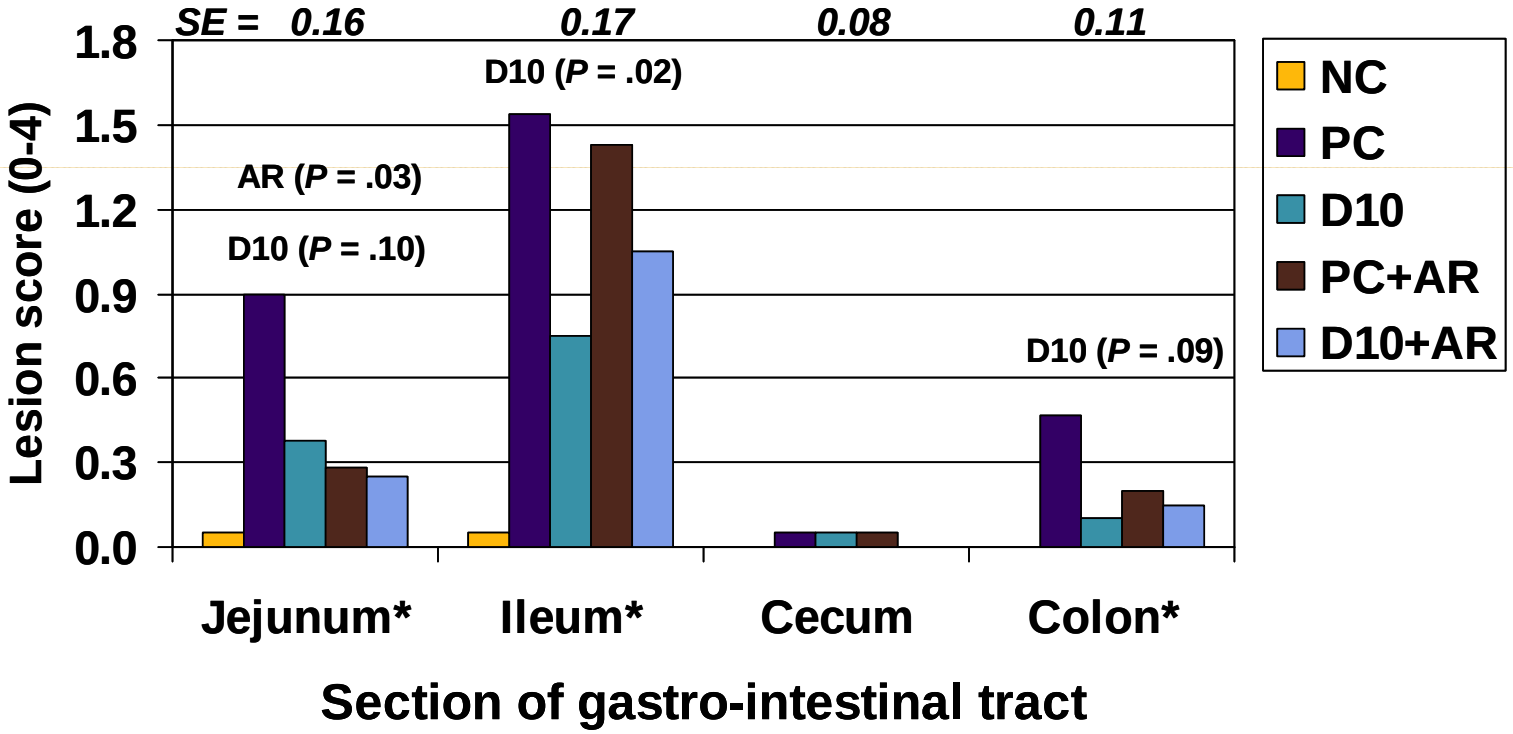


Effect of Dietary Treatment on Lesion Length (21 d Post-Challenge)



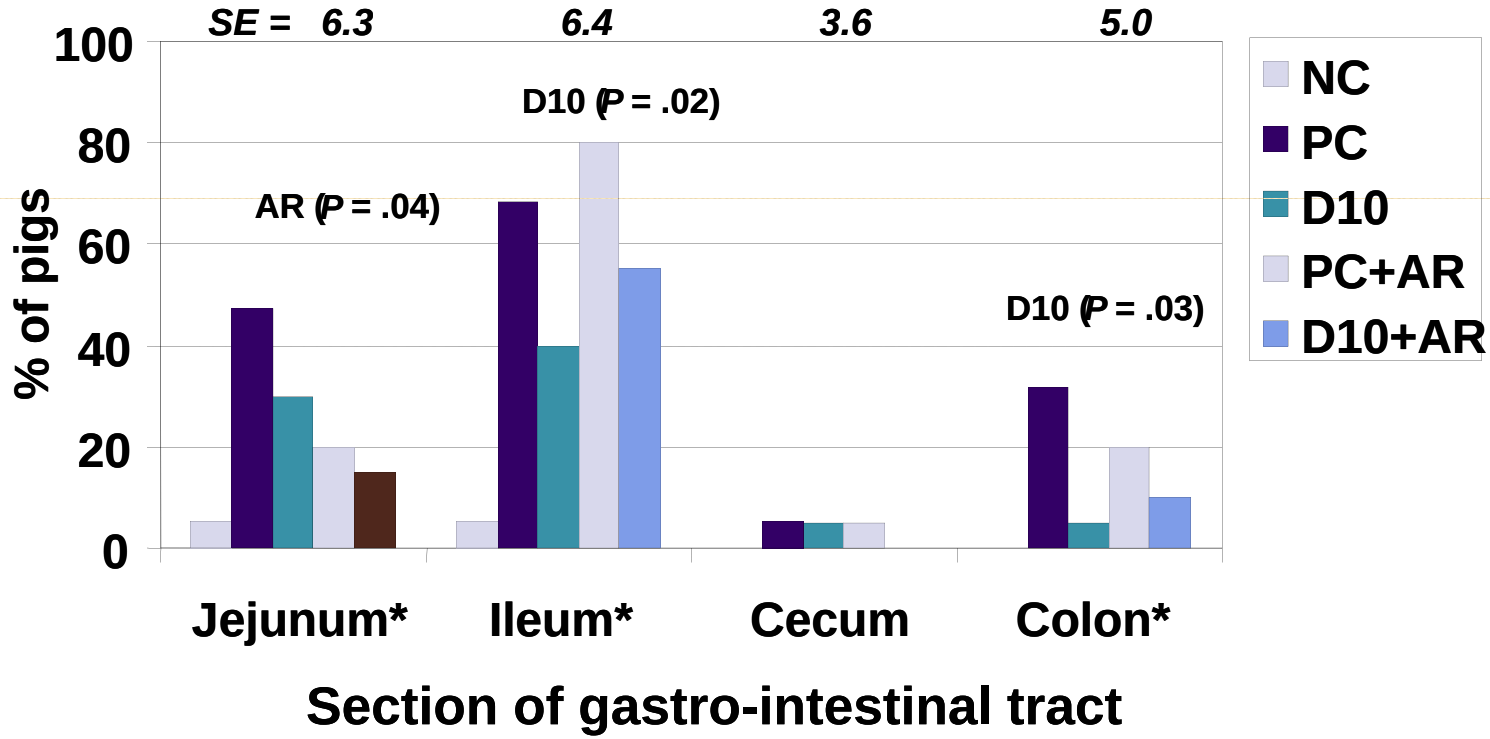
* Effect of disease challenge ($P < .01$).

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 ($P < .01$).

Effects of Feeding DDGS Diets on Swine Manure Characteristics

Effects of Feeding Diets Containing DDGS on Manure Nutrient Composition and Gas and Odor Emissions

- **Fecal excretion increases**
  - Decrease in dry matter digestibility
- **Urine excretion not affected**
  - No effect on water disappearance
- **N excretion increases**
  - Increased dietary crude protein (N)
  - Minimized by using synthetic amino acids
- **P excretion may vary**
  - Reduced when feeding < 20% DDGS + phytase and formulating on available P basis
  - Increased when feeding > 20% DDGS due to excess dietary P
- **No effect** on:
  - **Hydrogen sulfide**
  - **Ammonia**
- **No effect on odor detection levels**

Key Points

- DDGS
  - an excellent alternative ingredient
  - dramatically reduces production costs
  - maintain acceptable performance
    - up to 30% in all phases of production
    - up to 50% in gestation
  - new "tools" allow:
    - economically significant, accurate value assessments among sources
    - accurate nutrient loading values by source to manage nutrient variability

Key Points

- DDGS challenges
  - flowability
  - pelleting
  - added antioxidants (e.g vitamin E) to improve metabolic oxidation balance?
  - pork fat quality
    - bacon appearance and shelf life stability
    - acceptance in the export market (Japan)
  - meeting "natural" pork claims due to undefined regulations on "antibiotic-free"

Key Points

- Benefits
  - Feeding diets containing DDGS
    - Appear in some situations to improve gut health of grower-finisher pigs
    - Can reduce manure P levels with the use of phytase
    - May improve litter size weaned when fed at high levels to gestating and lactating sows
    - SIGNIFICANTLY REDUCES FEED COST AND TOTAL COST OF PRODUCTION!

University of Minnesota DDGS Web Site

www.ddgs.umn.edu

We have developed a DDGS web site featuring:

* nutrient profiles and photos of DDGS samples
* research summaries
  - swine, poultry, dairy, & beef
  - DDGS quality
* presentations given
* links to other DDGS related web sites
* international audiences