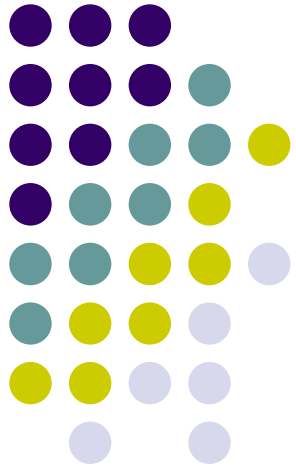
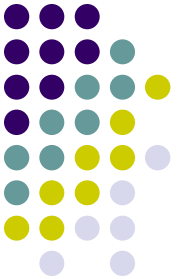
What We Know About Feeding Corn DDGS to Swine

Dr. Jerry Shurson
Department of Animal Science
University of Minnesota

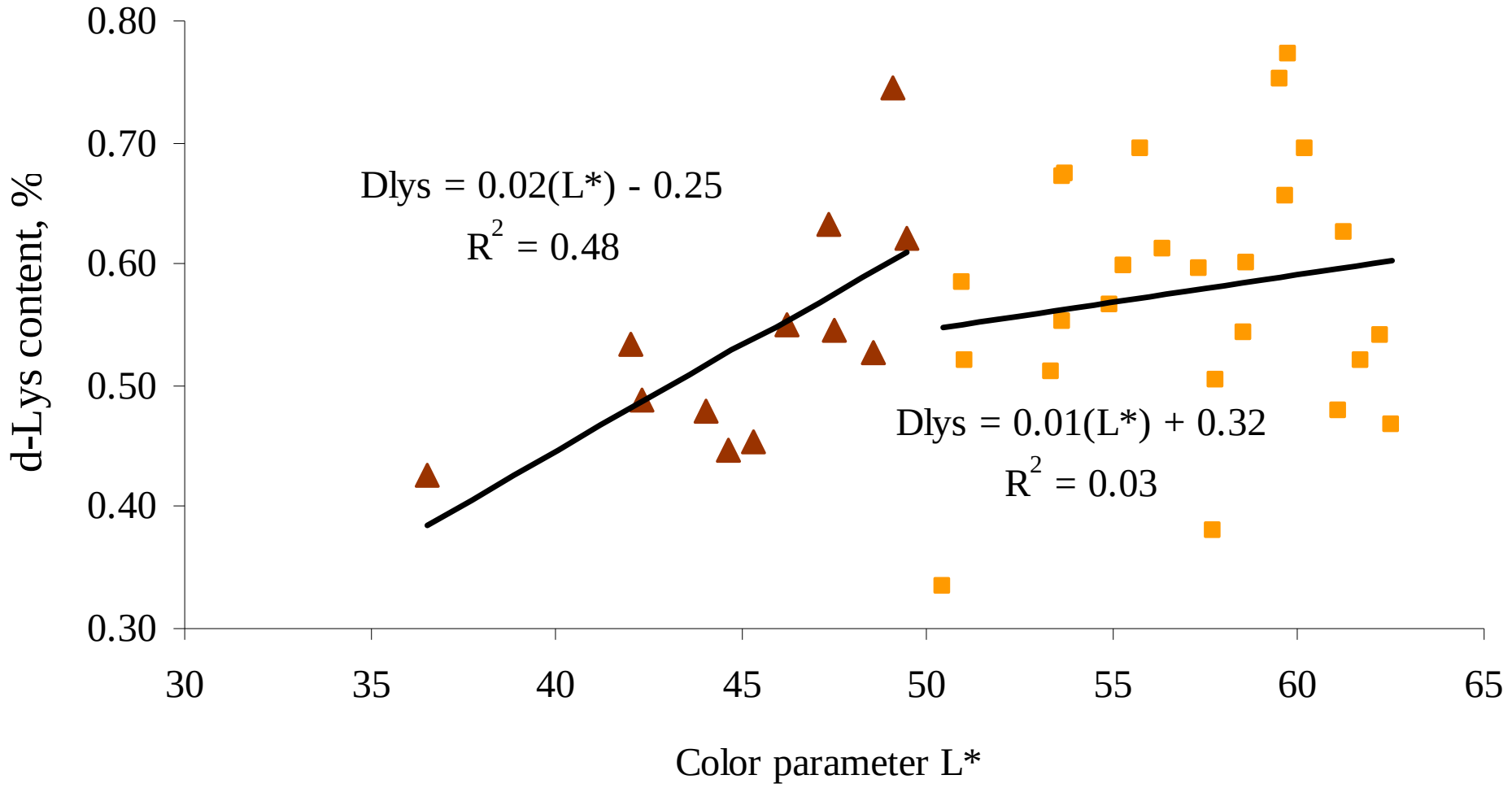


Nutritional Characteristics of DDGS for Swine

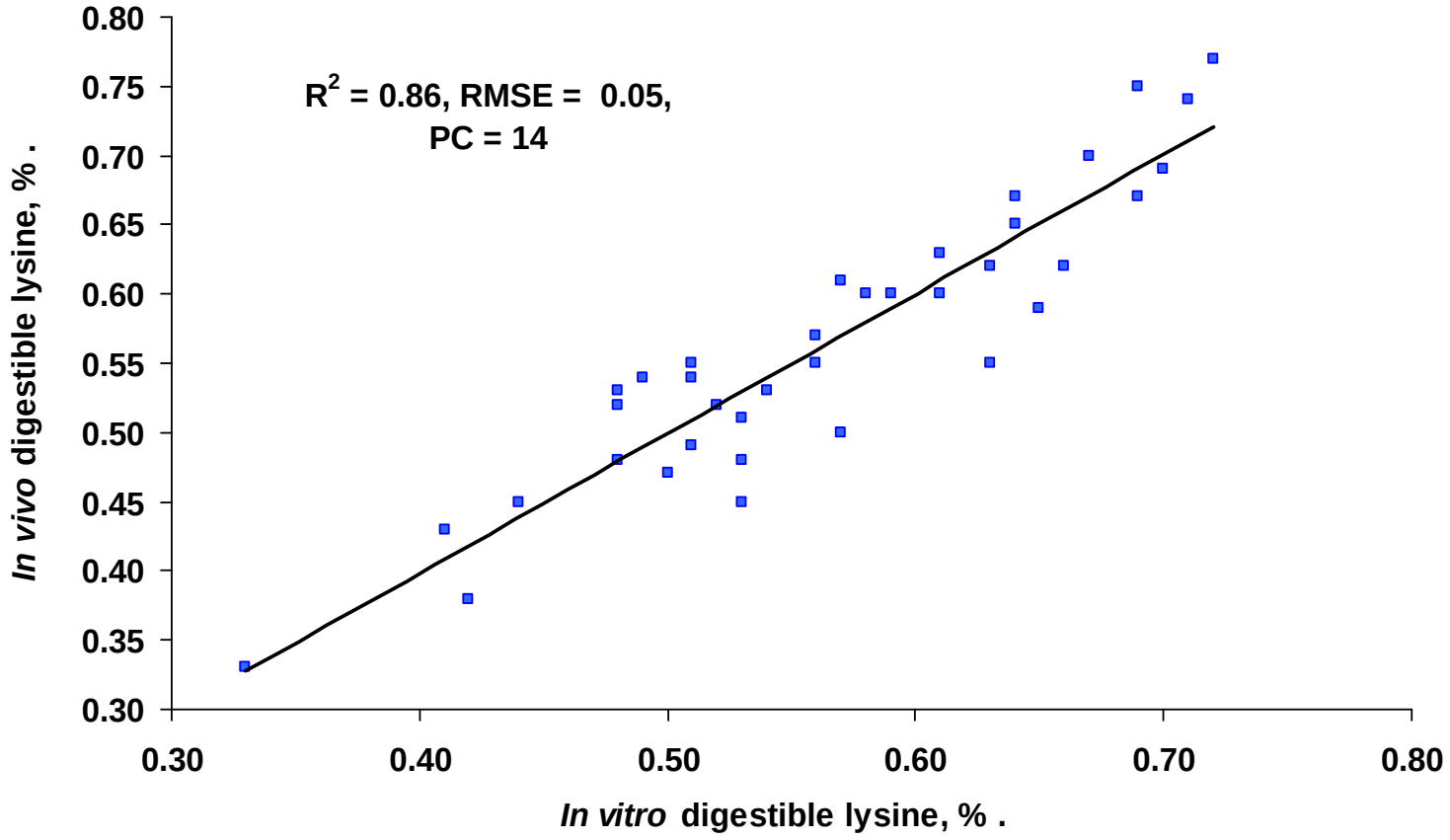


- DDGS ME = corn ME
- Amino acid content and digestibility variable
  - Total lysine (0.61-1.06% DM basis)
  - Standardized true lysine digestibility (44-67%)
- High digestible P
  - Reduce diet inorganic P supplementation
  - May reduce manure P excretion
- Partially replaces some corn, soybean meal,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

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

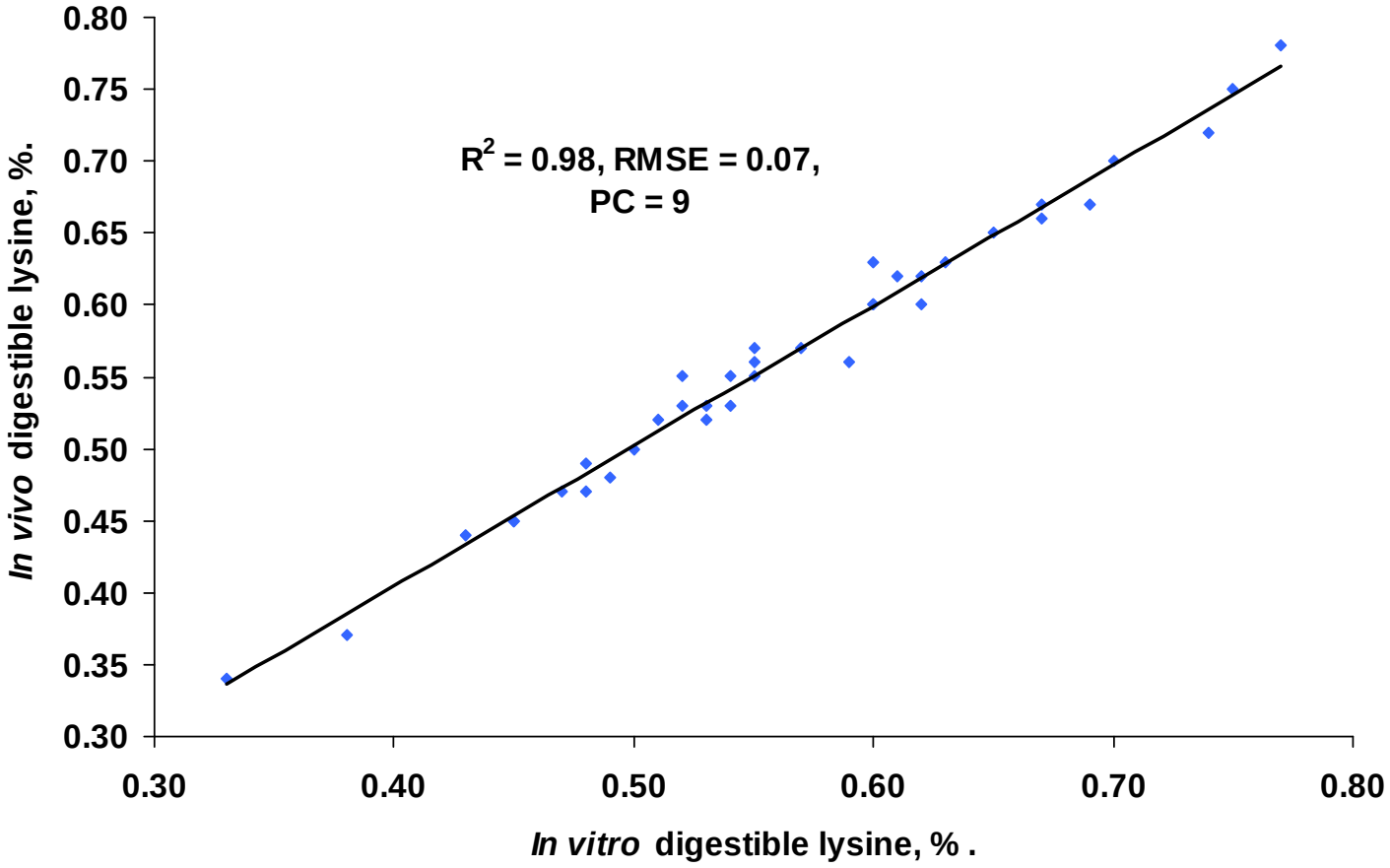


Prediction of Digestible Lysine from Optical Density (400 to 700 nm)



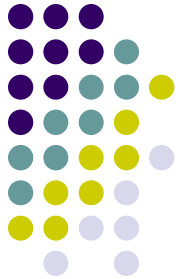
Urriola et al. (2007)

Prediction of Digestible Lysine in DDGS Using Front Face Fluorescence



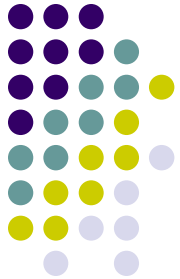
Urriola et al. (2007)

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

Quick Calculation of Feed Cost Savings



Thumb rule:

Additions/1000 kg diet

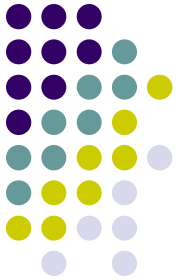
+ 100 kg DDGS x _____ $/kg = $_____
+ 1.5 kg limestone x _____ $/kg = $_____
TOTAL ADDITIONS (A) $_____

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

Current Commercial Dietary DDGS Inclusion Rates and Estimated Usage in the U.S.



- 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

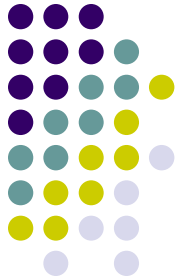
Maximum Inclusion Rates of High Quality DDGS in Swine Diets

(Based Upon University of Minnesota Performance Trials)

- Nursery pigs (> 7 kg)
  - 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

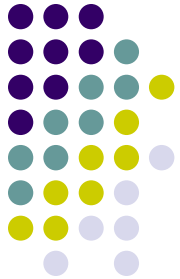
DDGS Issues/Challenges



1. By-product variability
    a. nutrient content
    b. nutrient digestibility
    c. physical characteristics
2. Ability to pellet DDGS diets
3. Lack of a quality grading system
    a. difficult sourcing to obtain desired quality and price
4. Lack of standardized testing procedures
5. Need for quality management and certification
6. Risk of mycotoxins

- Presence of antimicrobial residues?

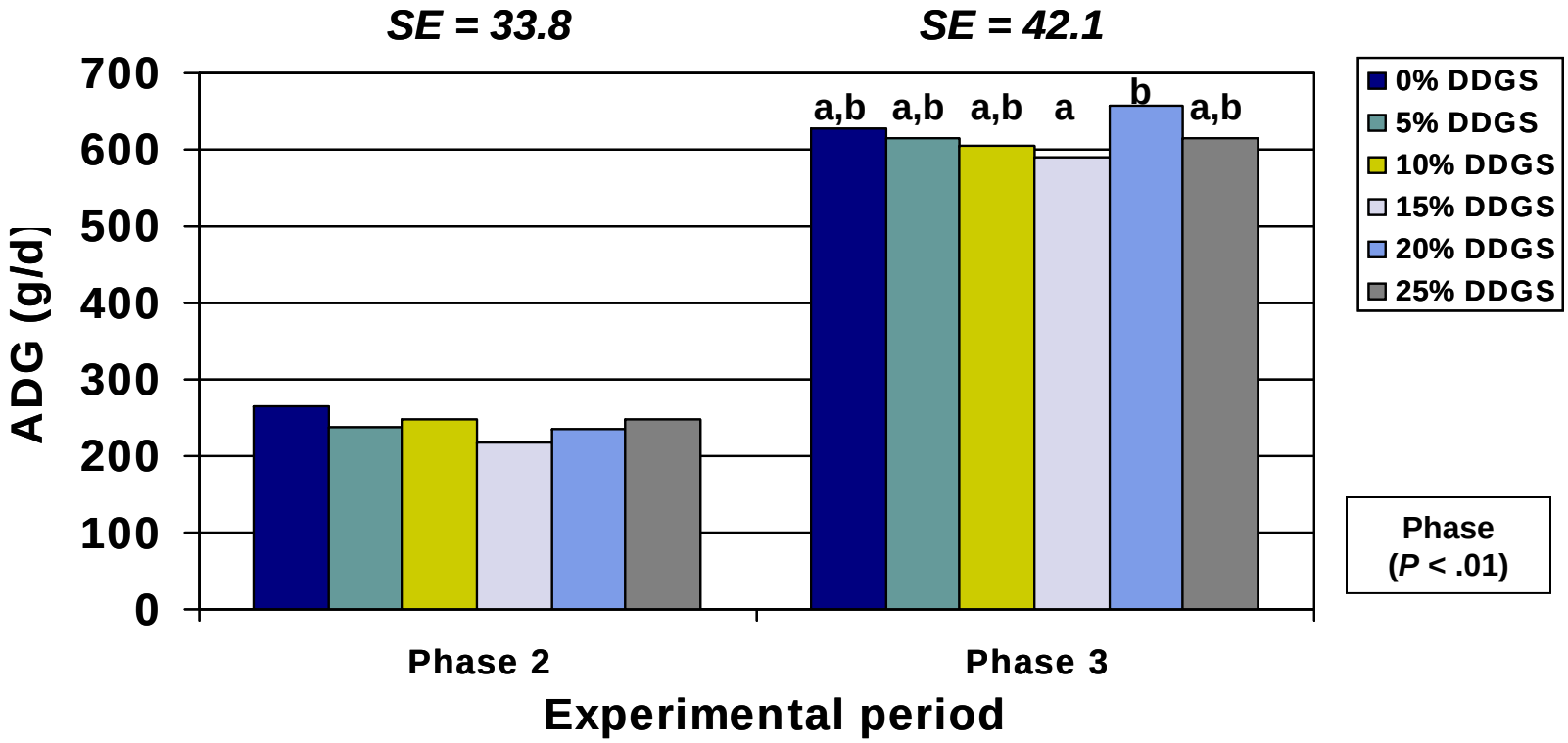
Other Barriers Limiting DDGS Use in Swine Diets



- 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

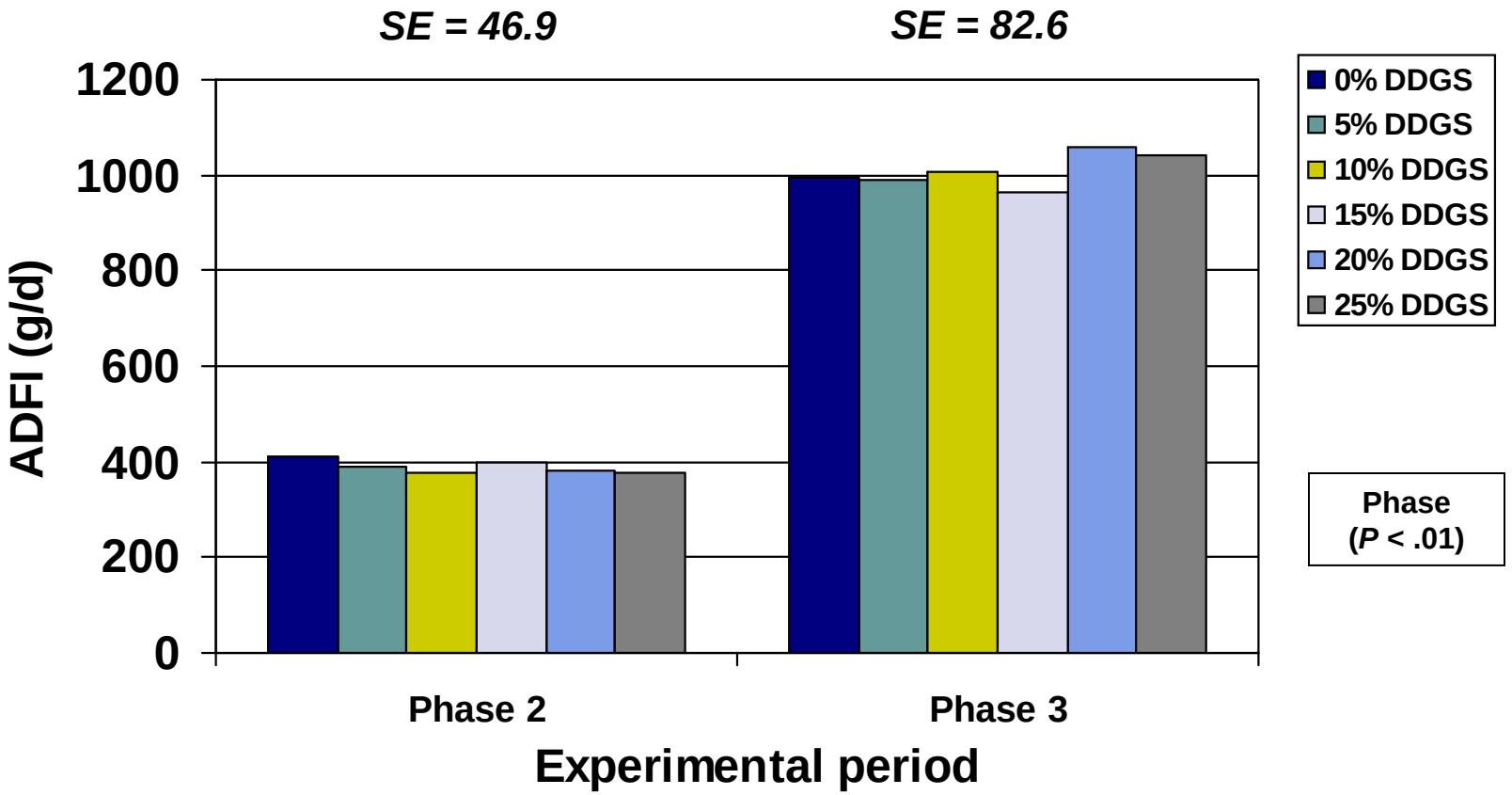
Feeding High Quality DDGS to Weaned Pigs

Effect of DDGS Level on Growth Rate

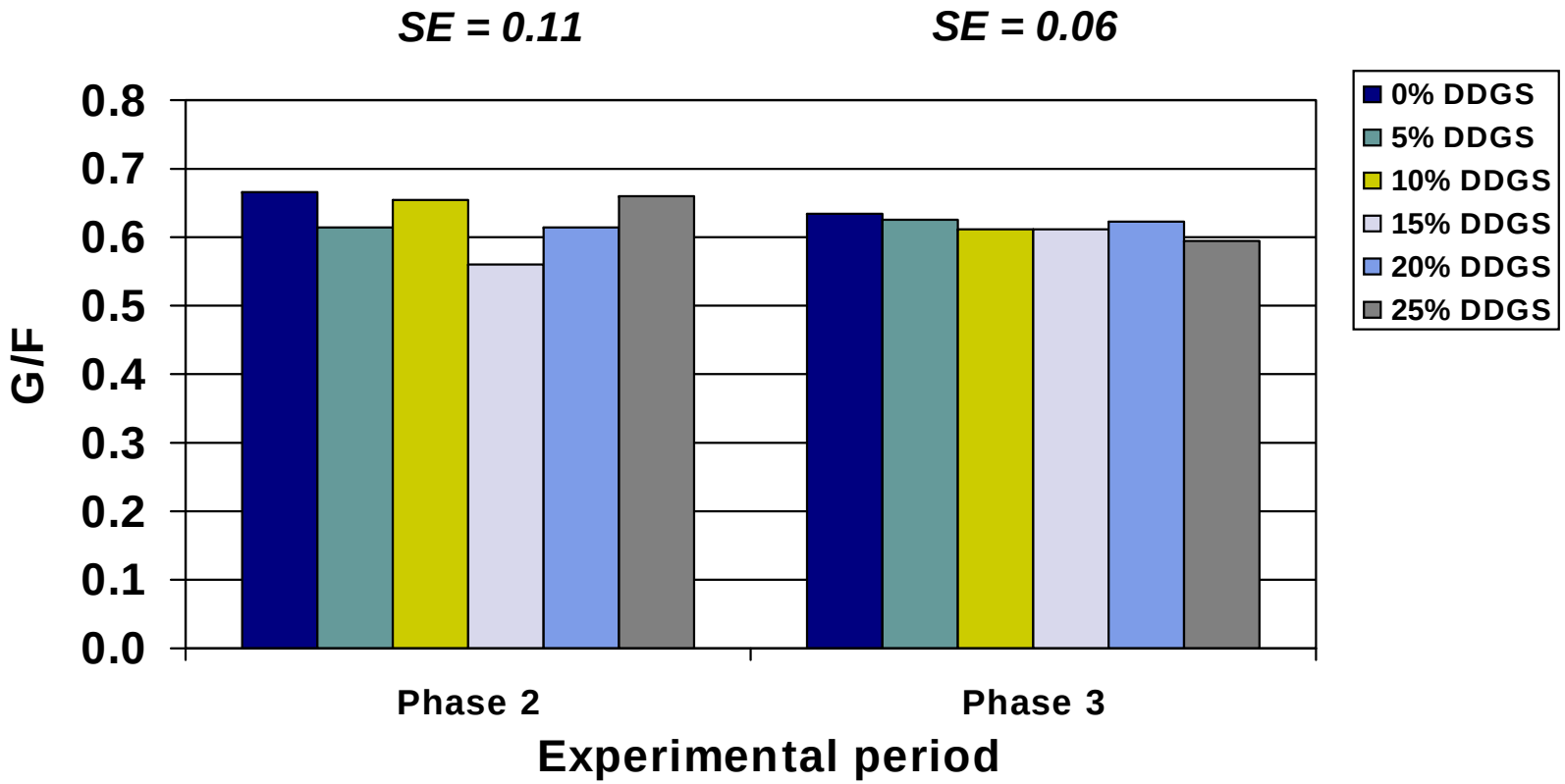


Means not sharing a common superscript letter are significantly different ($P < .05$)

Effect of DDGS Level on Average Daily Feed Intake



Effect of DDGS Level on Gain/Feed



Feeding High Quality DDGS to Grower-Finisher Pigs

Why Is There a Concern About Feeding Diets Containing DDGS on Pork Fat Quality?

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

Nutrient	Corn DDGS	Corn
Swine ME, kcal/kg	3,390	3,420
Crude fat, %	9.6	3.9
Linoleic acid (C18:2), %	5.32	1.92
Oleic acid (C18:1), %	2.47	0.94

Current Pork Fat Quality Standards

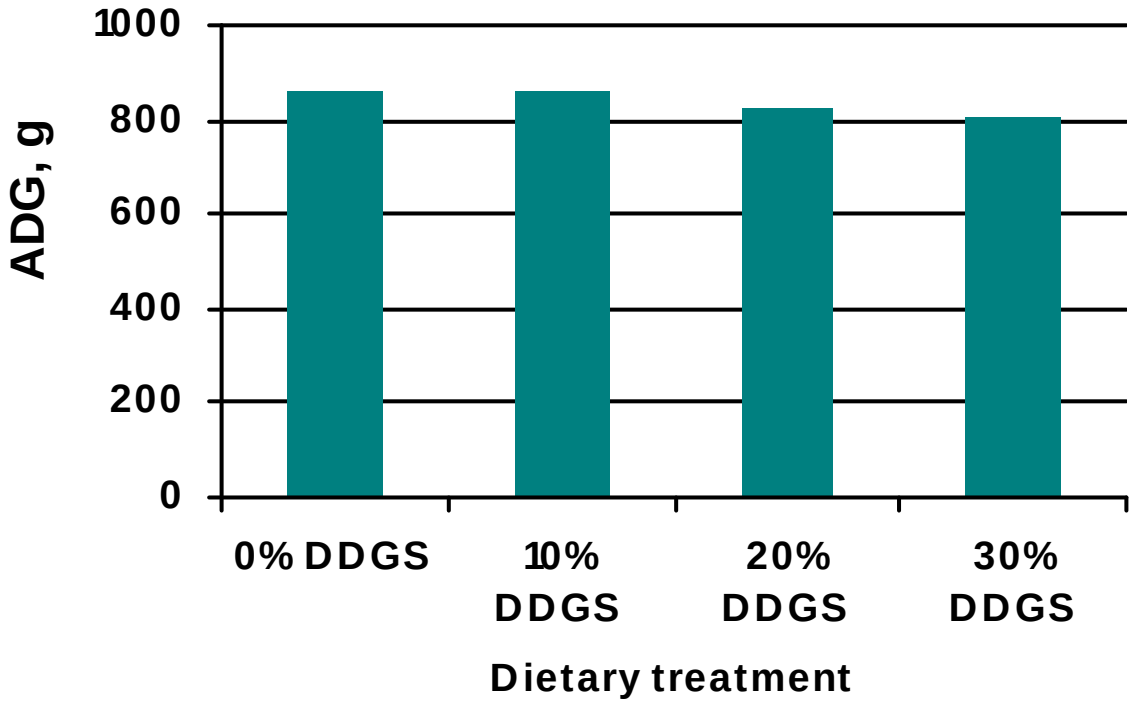
- Based on Iodine Value (IV)
  - ratio of unsaturated:saturated fatty acids
- Maximum IV
  - 70 – Danish Meat Research Institute
  - 72 – National Pork Producers Council
  - 74 – Boyd et al. (1997)
- Various adipose tissue sites are affected differently by dietary fatty acid composition

Study 1 – “Worst Case Scenario”

Materials and Methods

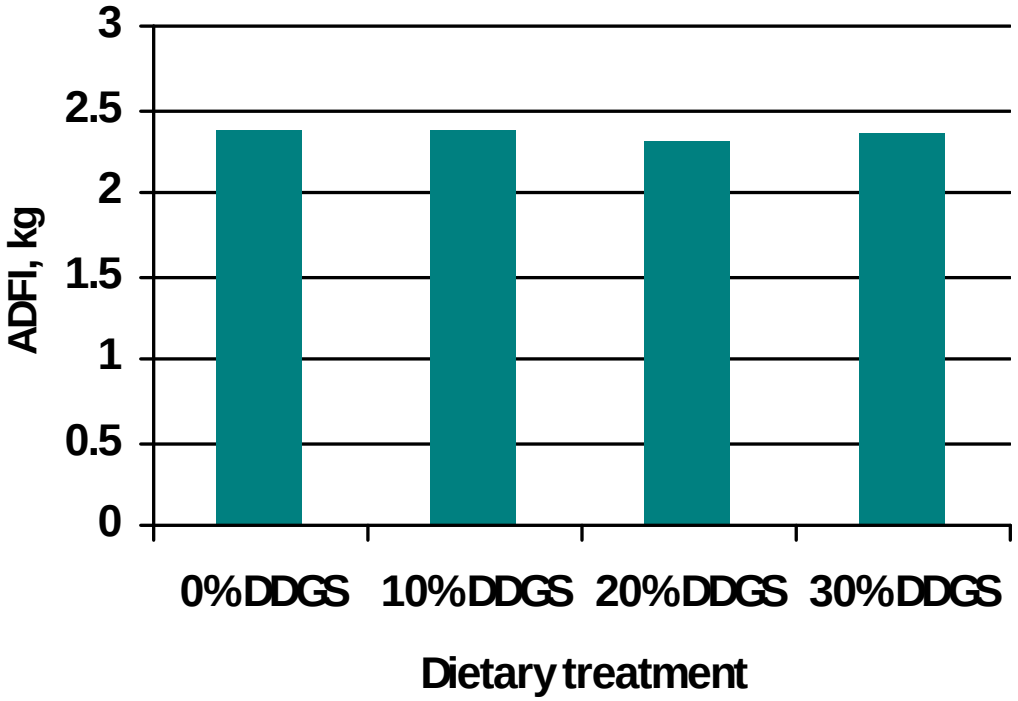
- 240 crossbred pigs (~ 63 lbs initial BW)
  - Pens randomly assigned to 1 of 4 experimental diets
    - 5-phase feeding program
  - 0, 10, 20, or 30% DDGS diets
    - **formulated on total lysine basis**
    - **diets contained up to 4% soybean oil**
  - 24 pens, 10 pigs/pen, 6 replications/trt

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



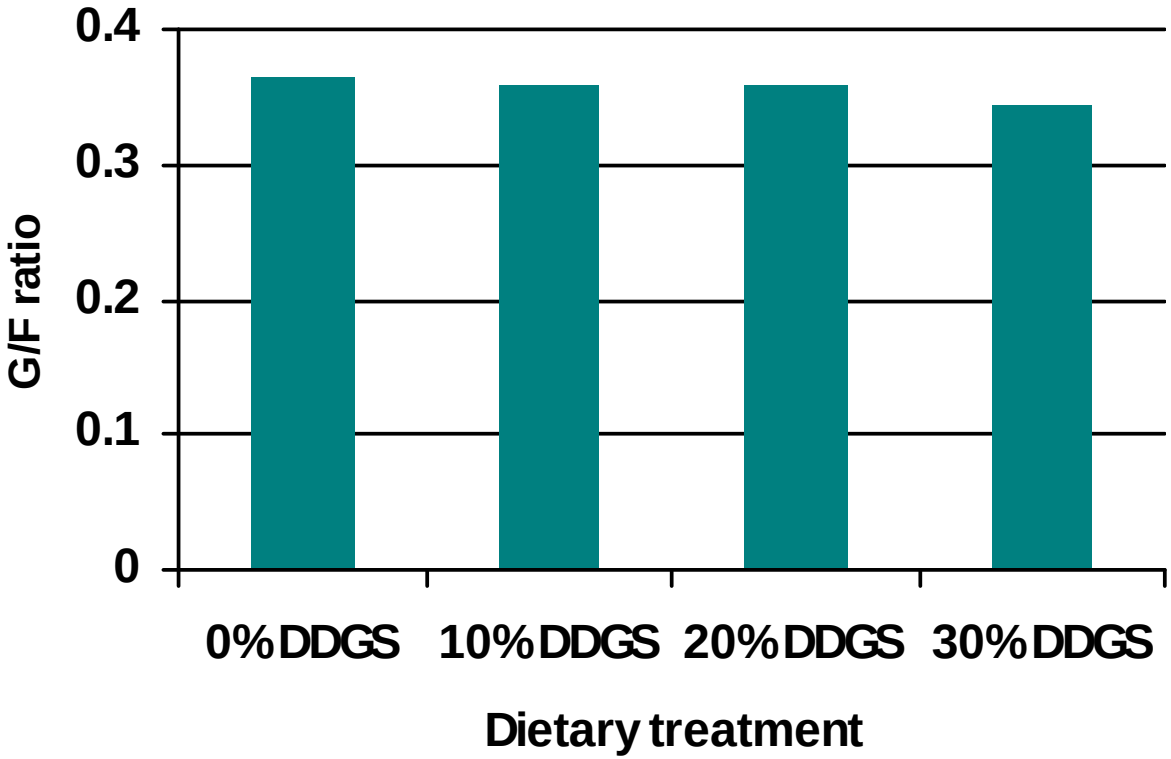
0 % and 10 % DDGS > 20% and 30% DDGS (P < .10)

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



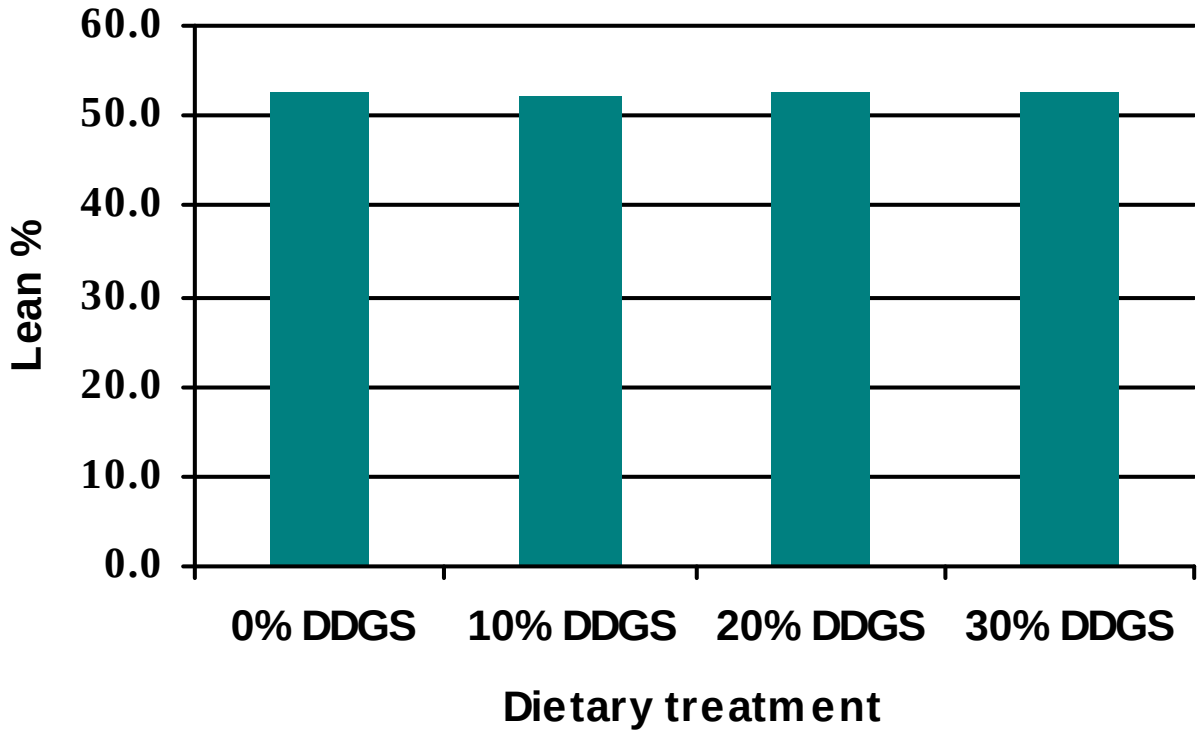
No significant differences among dietary treatments

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



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

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, kg	117	119	113	112
Carcass weight, kg	85.7[c]	86.6[c]	81.6[d]	80.7[d]
Dressing %	73.4[c]	72.8[c]	72.1[d]	71.9[d]
Fat depth, mm	21.3	21.8	21.0	20.5
Loin depth, mm	56.5[ac]	54.0[b]	54.8[c]	51.5[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
[b] 1=pale pinkish gray/white; 2=grayish pink; 3=reddish pink; 4=dark reddish pink; 5=purplish red; 6=dark purplish red
[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

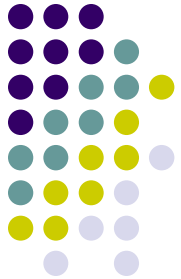
Fat Quality Characteristics of Market Pigs Fed Corn-Soy Diets Containing 0, 10, 20, and 30% DDGS

	0 %	10%	20%	30%
Belly thickness, cm	3.15[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).

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

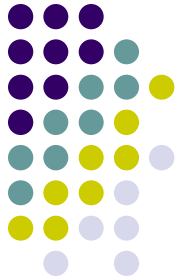
U of M/Land O' Lakes
Pork Fat Quality Field Study (2006)



- 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

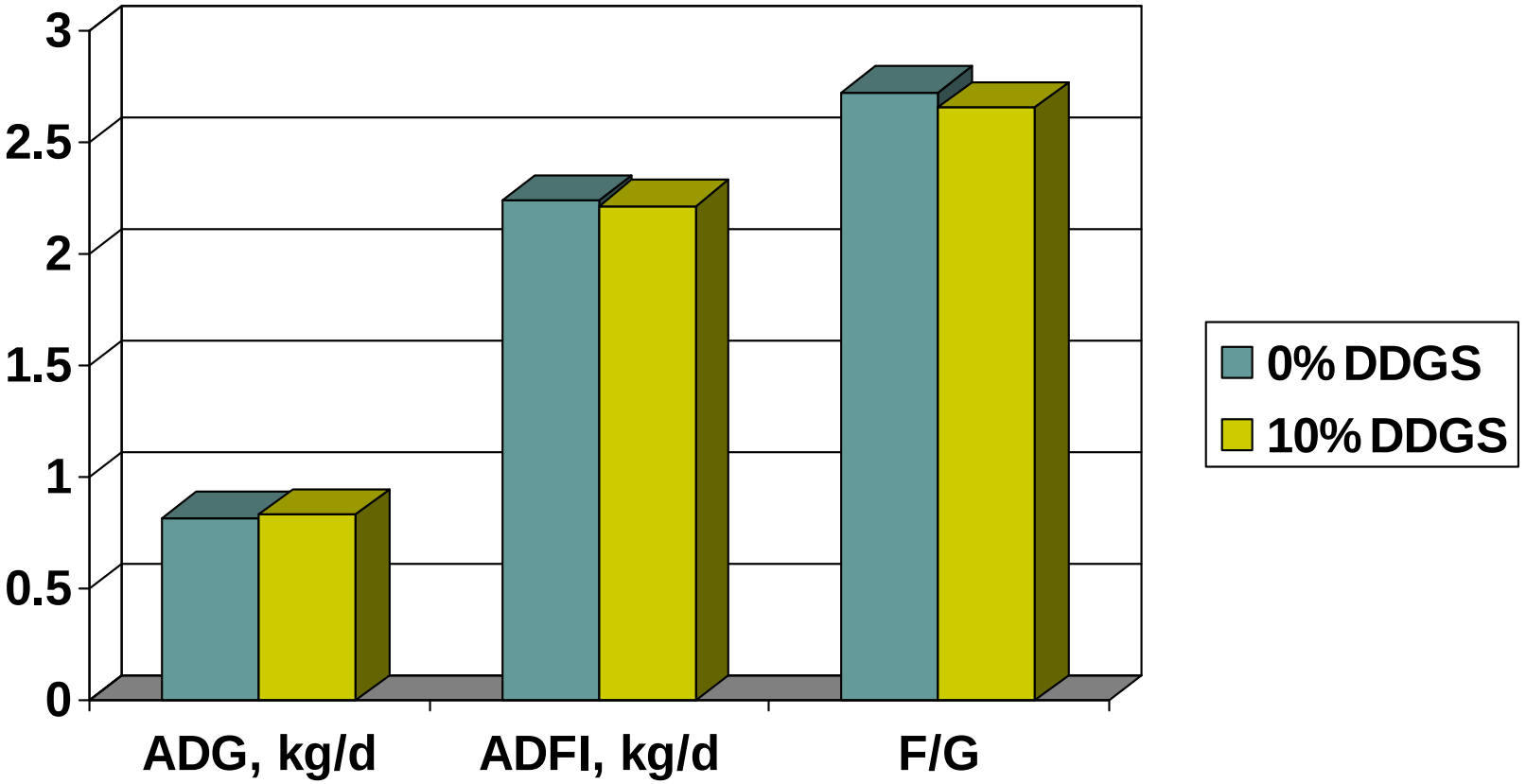
- Genetics
  - Monsanto Genepacker sows
  - Monsanto EB terminal semen

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
  - 8-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)



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

Measurement	0% DDGS Diets	10% DDGS Diets
Carcass weight, kg	96.1	95.2
Last rib backfat, mm	27.3	27.8
Tenth rib backfat, mm	25.3	24.8
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.

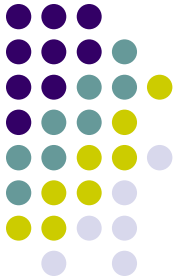
Mid-Belly Fat Quality Characteristics of Grow-Finish Pigs Fed 0 or 10% DDGS Diets (UM/LOL Field Trial)

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
Iodine 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[c]**	**45.12[d]**
18:2 linoleic acid, %	**11.94[c]**	**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[c]**	**49.47[d]**
PUFA, %	**14.02[c]**	**16.11[d]**
Total Omega 3, %	0.98	0.96
Total Omega 6, %	**13.02[c]**	**15.14[d]**
Omega 6:Omega 3 ratio	**13.28[c]**	**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

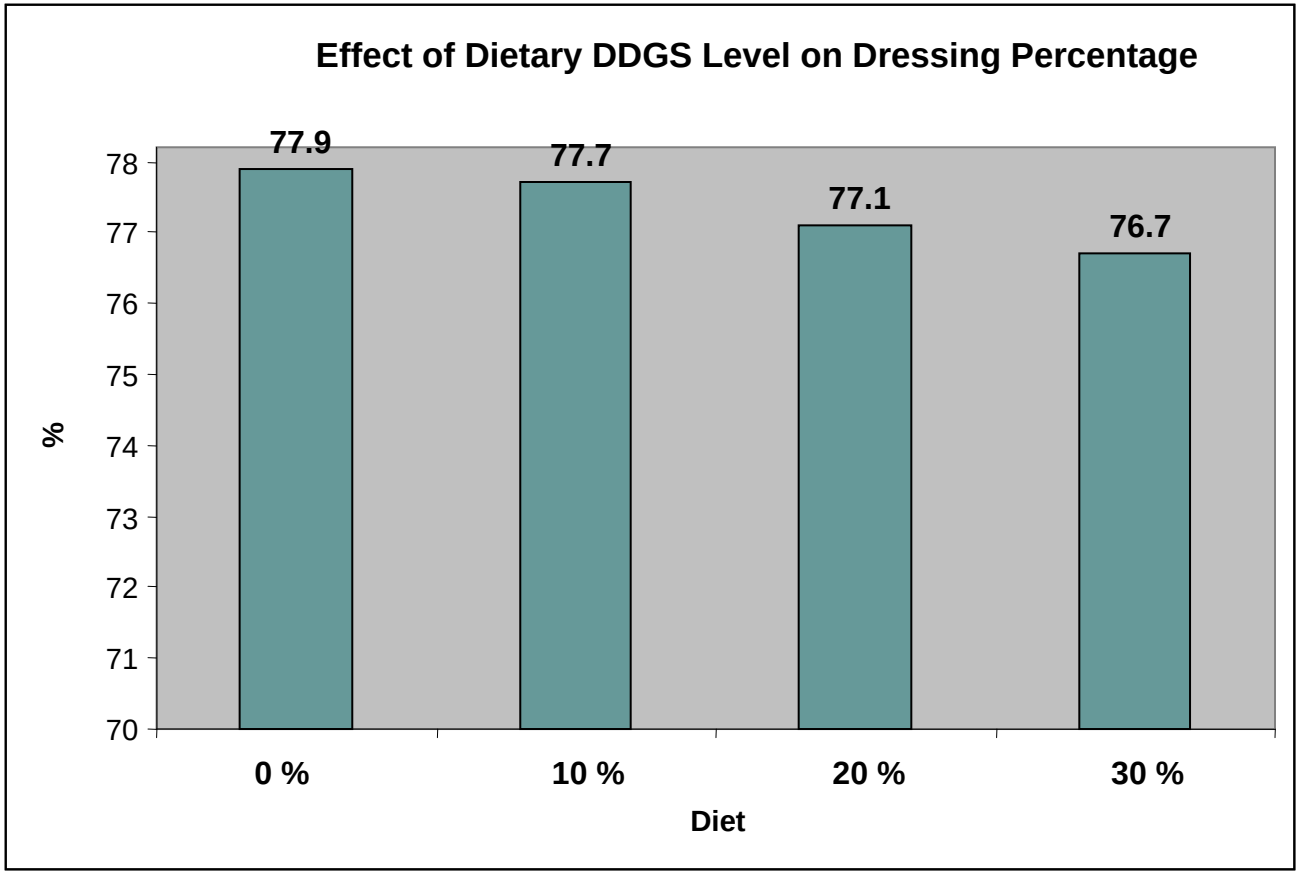


	0% DDGS	10% DDGS	20% DDGS	30% DDGS
Initial wt., kg	22.5	22.8	22.5	22.5
Final wt., kg	114	115	114	113
ADG, kg/d	0.92	0.92	0.92	0.91
ADFI, kg/d[a]	2.57	2.55	2.49	2.46
F/G[a]	2.79	2.76	2.71	2.70

[a] Linear effect of DDGS level

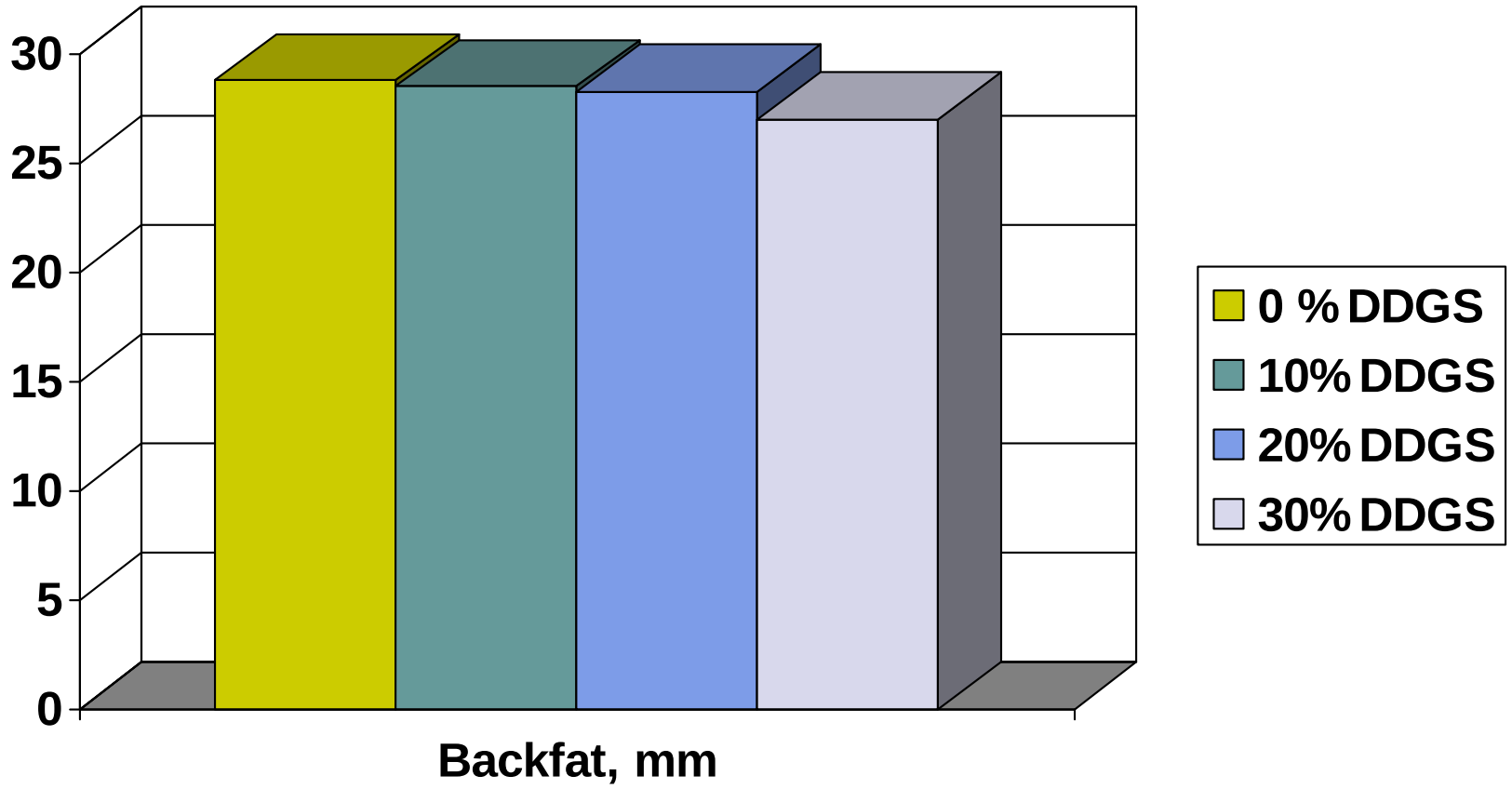
Data from 64 pens, 16 pens/treatment (Xu et al., 2007)

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



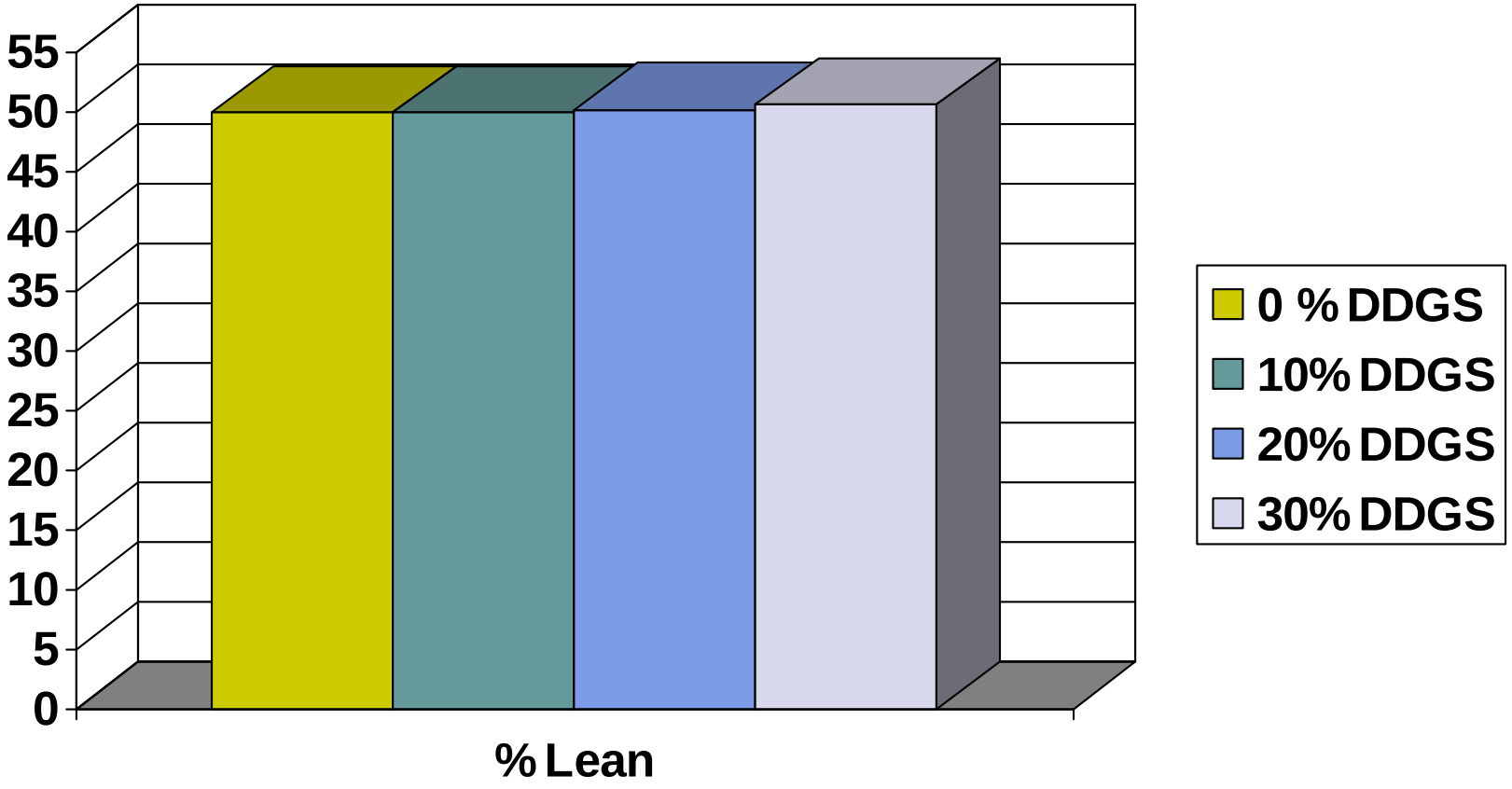
Xu et al. (2007)
Linear effect ($P < 0.01$)

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)

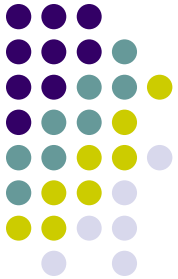
Effects of Dietary DDGS Level on % Carcass Lean



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



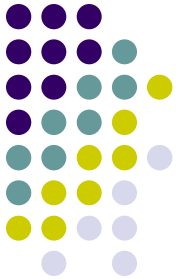
- **No difference in:**
  - ultimate pH
  - subjective color score
  - drip loss on day 0, 14, 21, or 28 post-harvest
  - lipid oxidation in loins at 28 days of shelf storage

- 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**

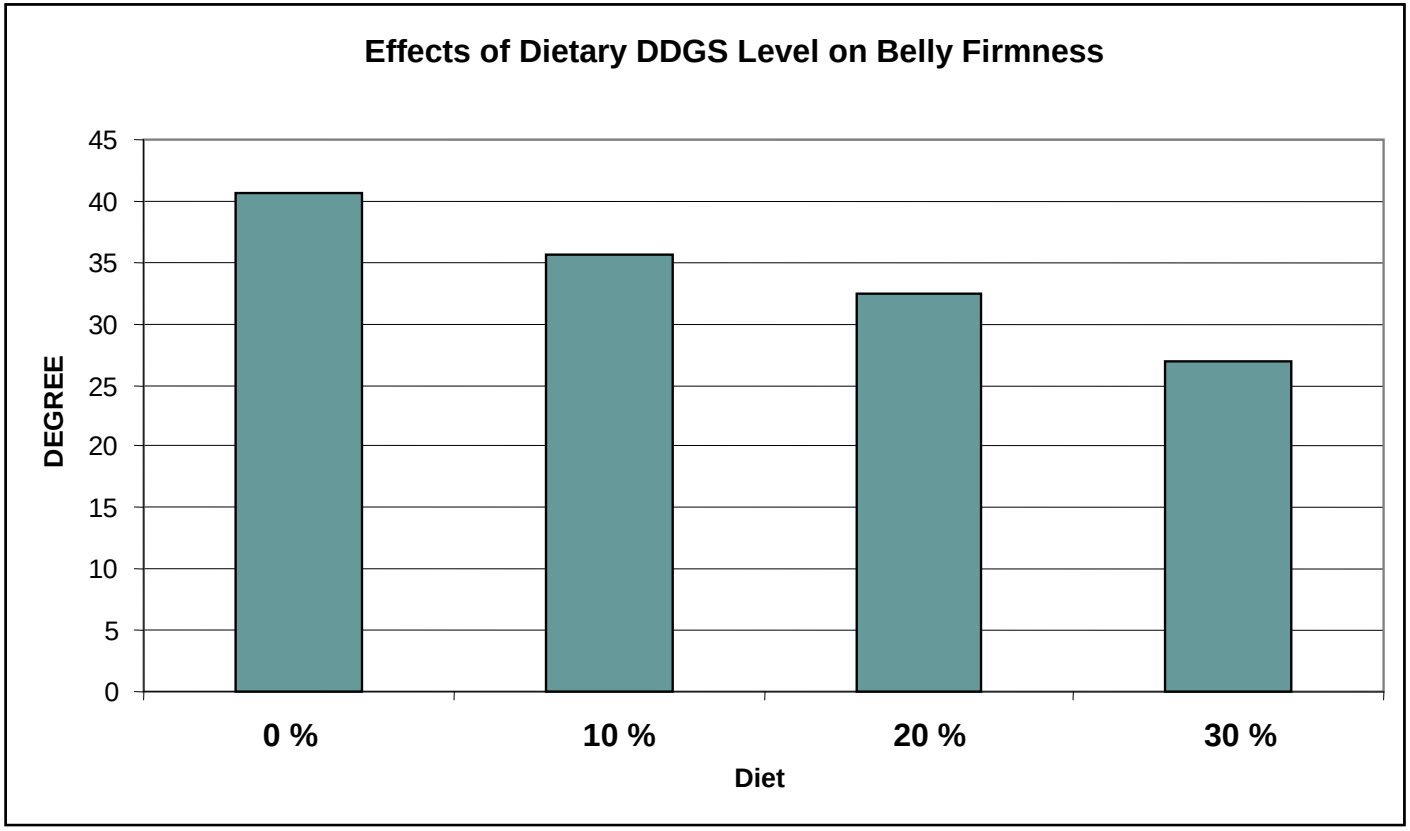
- Pigs fed the 30% DDGS diets had loins that were slightly less red
  - **Within accepted NPPC quality standards**

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



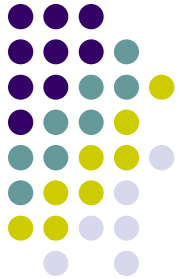
- **No difference in:**
  - Cooking loss
  - Flavor
  - Off flavor
  - Tenderness
  - Juiciness
  - Overall eating quality

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*

Study 4 - The effects of increasing DDGS level and withdrawal intervals on growth performance, pork quality, and pork fatty acid composition in grower-finisher pigs

Experimental Design

- Completely randomized arrangement with 9 treatment combinations
- Nine treatment combinations include:
  - Control: D0-0wk (8 pens)
  - D15-0wk (5 pens)
  - D15-3wk (5 pens)
  - D15-6wk (5 pens)
  - D15-9wk (5 pens)
  - D30-0wk (5 pens)
  - D30-3wk (5 pens)
  - D30-6wk (5 pens)
  - D30-9wk (5 pens)

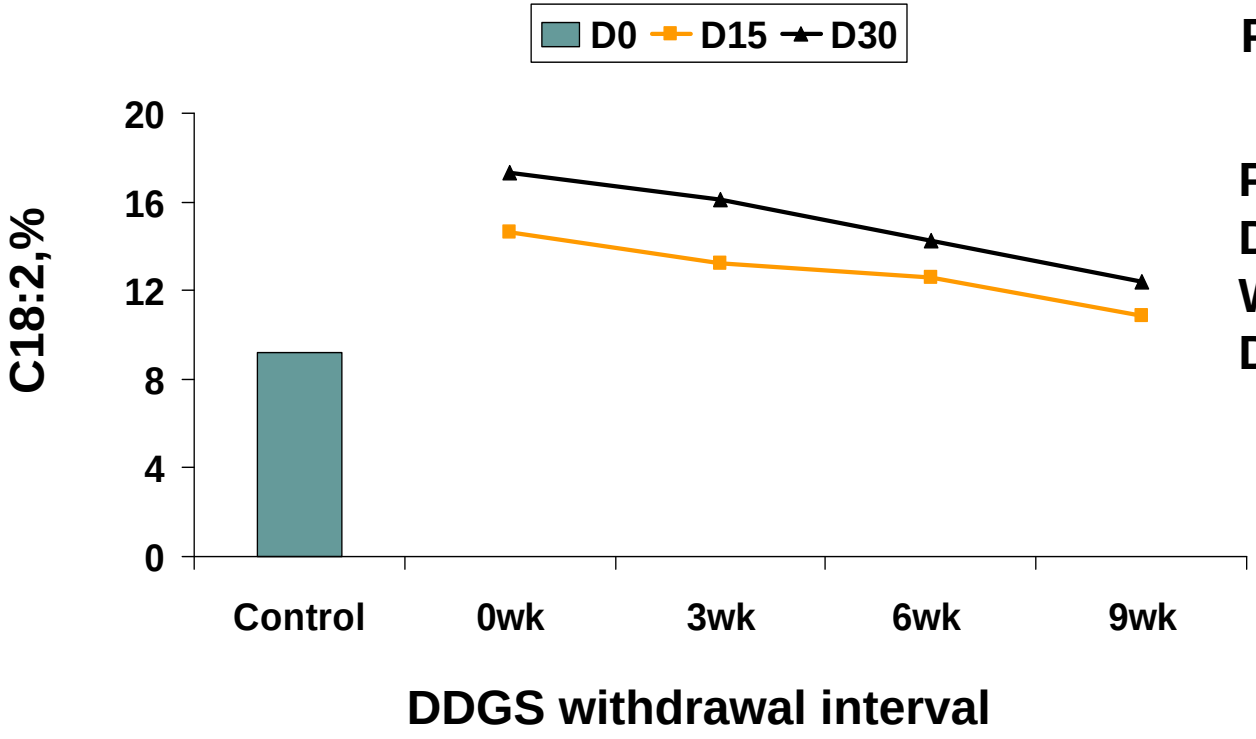
Effects of Dietary DDGS Level and Withdrawal Interval on Growth Performance and Carcass Weight

- No effect on ADG except
  - Control > D30 (0.92 kg/d vs. 0.87 kg/d, respectively)
- No effect on ADFI
- No effect on G/F
- No effect on carcass weight except
  - Control > D30 (94.9 kg vs. 92.4 kg, respectively)

Effects of Dietary DDGS Level and Withdrawal Interval on Carcass and Loin Quality

- No difference
  - Dressing %
  - Last rib backfat depth
  - Lean percentage
  - Loin firmness
  - Loin marbling
  - Subjective color score
  - Minolta color L*

Effects of Dietary DDGS Level and Withdrawal Interval on C18:2 Content of Belly Fat

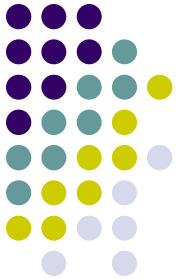


PSE = 0.67

P - value
DDGS level < 0.001
Withdrawal < 0.001
D × W = 0.67

All treatments > control (P < 0.05)

Effects of Dietary DDGS Level and Withdrawal Interval on Fatty Acid Content of Belly Fat and Belly Firmness



- **PUFA**
  - Increased with DDGS level
  - Decreased with DDGS withdrawal
    - Control = D15-9
- **Iodine value**
  - Increased with DDGS level
  - Decreased with DDGS withdrawal
    - Control = D15-9 and D30-9
- **Monounsaturated fatty acids**
  - Increased with DDGS level
- **Saturated fatty acids**
  - Decreased with DDGS level
  - Increased with DDGS withdrawal
- **Belly firmness**
  - D30-0 < control

Effects of Dietary DDGS Level And Withdrawal Interval on Fat Color

- No difference:
  - Japanese color score
  - Minolta color
    - L* (lightness)
    - a* (redness)
    - b* (yellowness)

Summary and Conclusions

- Increasing DDGS level from 0 to 30% in grower-finisher swine diets
  - Has minimal effects on pig growth performance
  - Linearly increases C18:2 content and IV of belly fat
  - Reduces belly firmness at 30% dietary DDGS level
- Withdrawing DDGS from the diet
  - C18:2 and IV of belly fat are reduced linearly
  - Acceptable pork fat quality (IV < 70) can be achieved in pigs
    - 15% dietary DDGS
    - 30% dietary DDGS with a 3 wk withdrawal interval

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

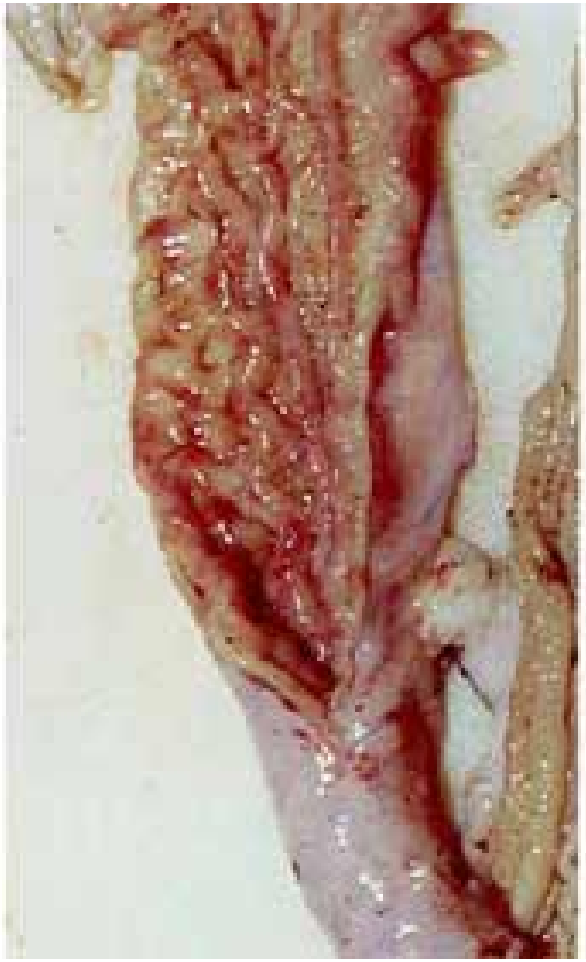
Effect of Feeding Diets Containing DDGS on Feed Intake of Growing Pigs (Published)

- No Effect
  - Hansen et al. (1997)
  - Cook et al. (2005)
  - DeDecker et al. (2007)
  - Xu et al. (2007)
  - Gaines et al. (2007)
  - Widmer et al. (2007)
- Decrease
  - Fu et al. (2004)
  - Hastad et al. (2005)
  - Lineen et al. (2006)
  - Whitney et al. (2006)
  - Hinson et al. (2007)

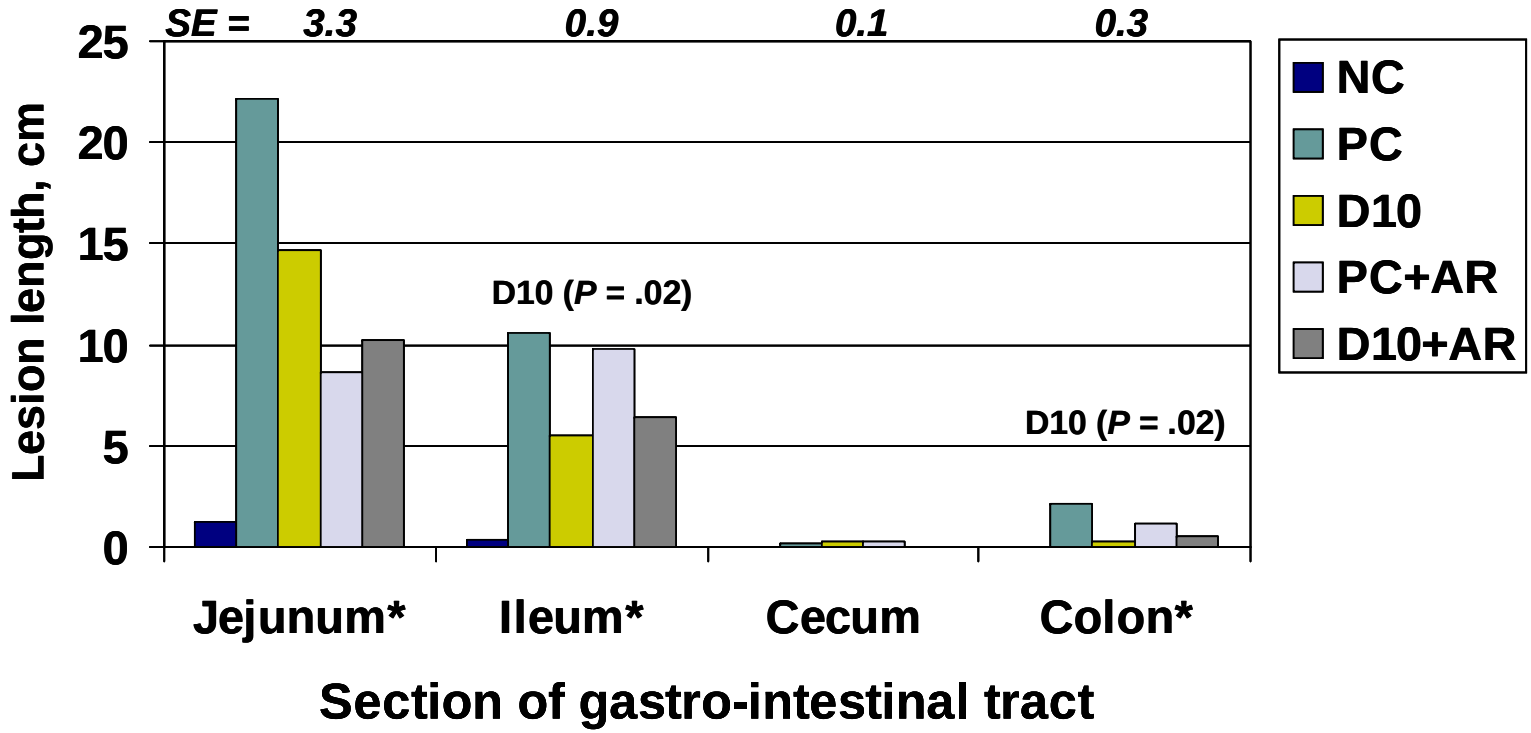
Does Feeding DDGS Improve Gut Health of Growing Pigs?

Healthy

Ileitis

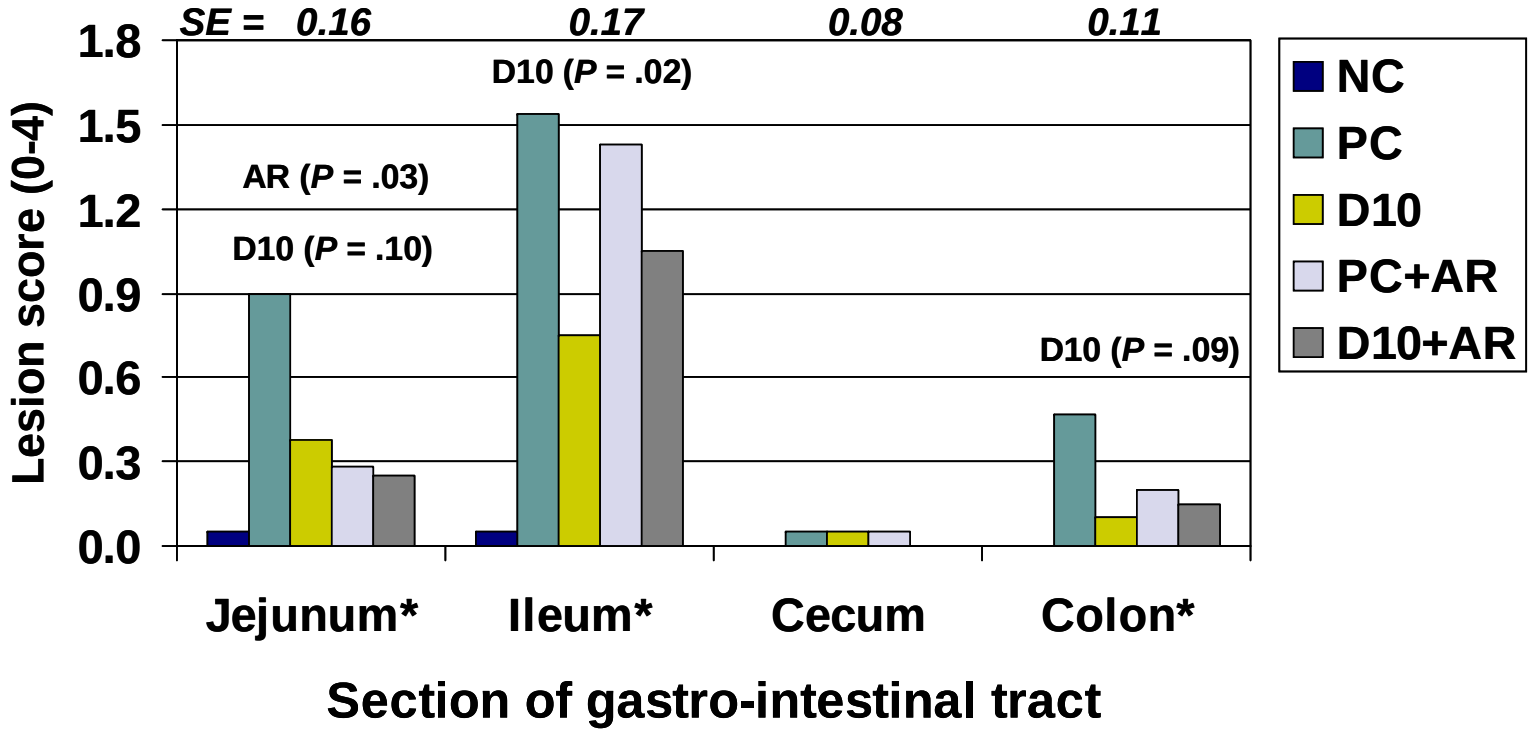


Effect of Dietary Treatment on Lesion Length (21 d Post-Challenge)



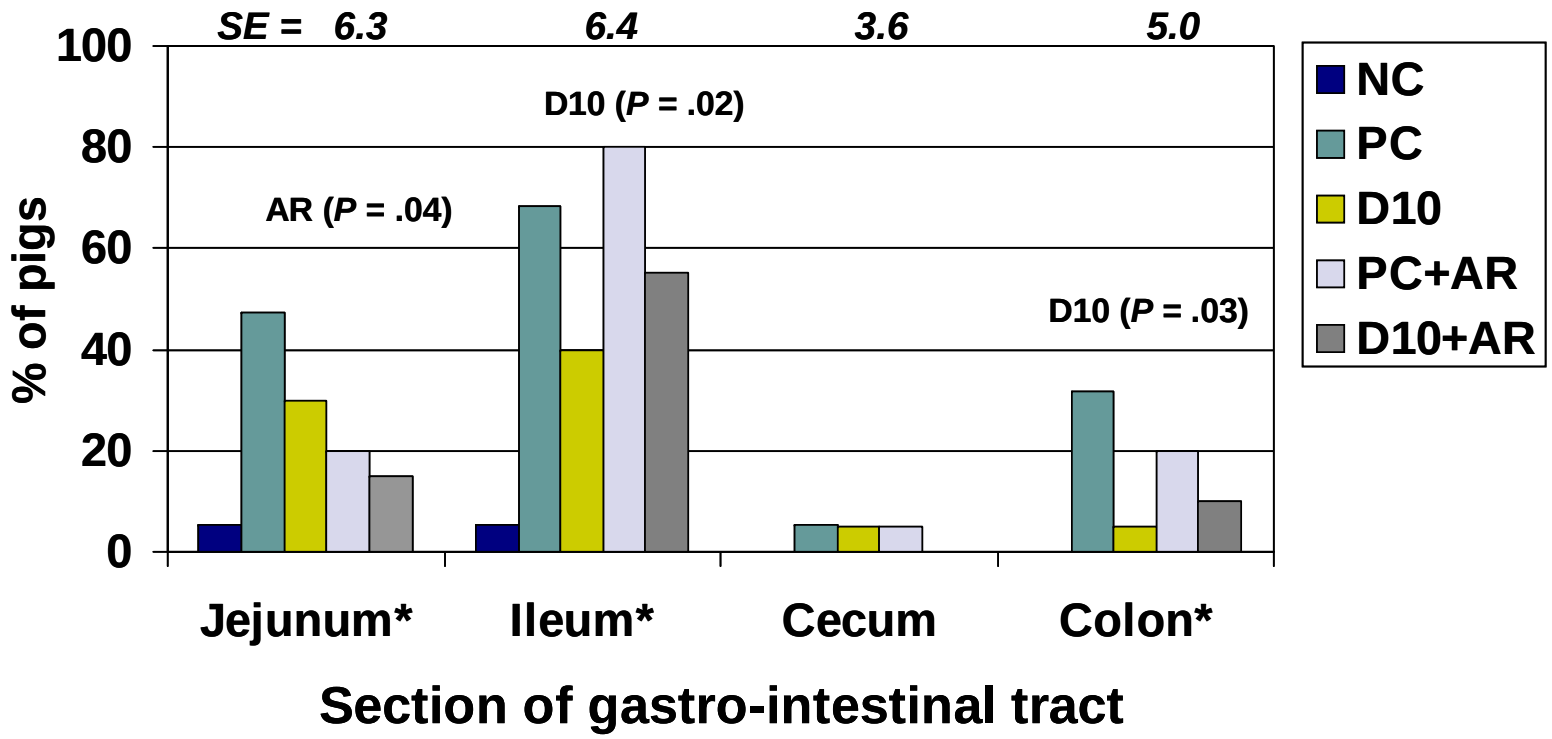
* Effect of disease challenge ($P < .01$).

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



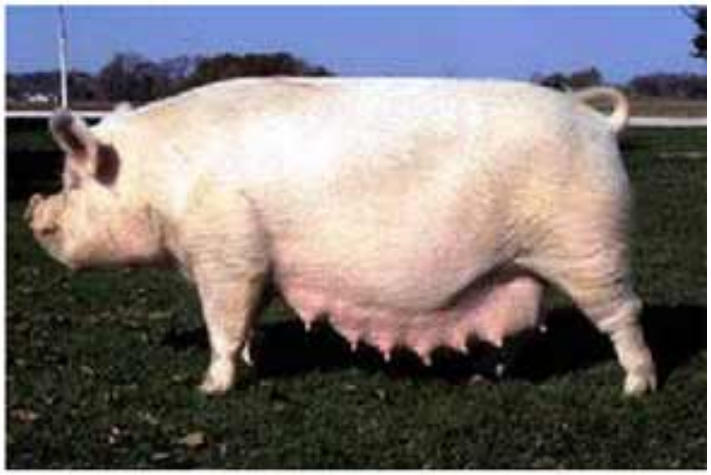
* Effect of disease challenge ($P < .01$).

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

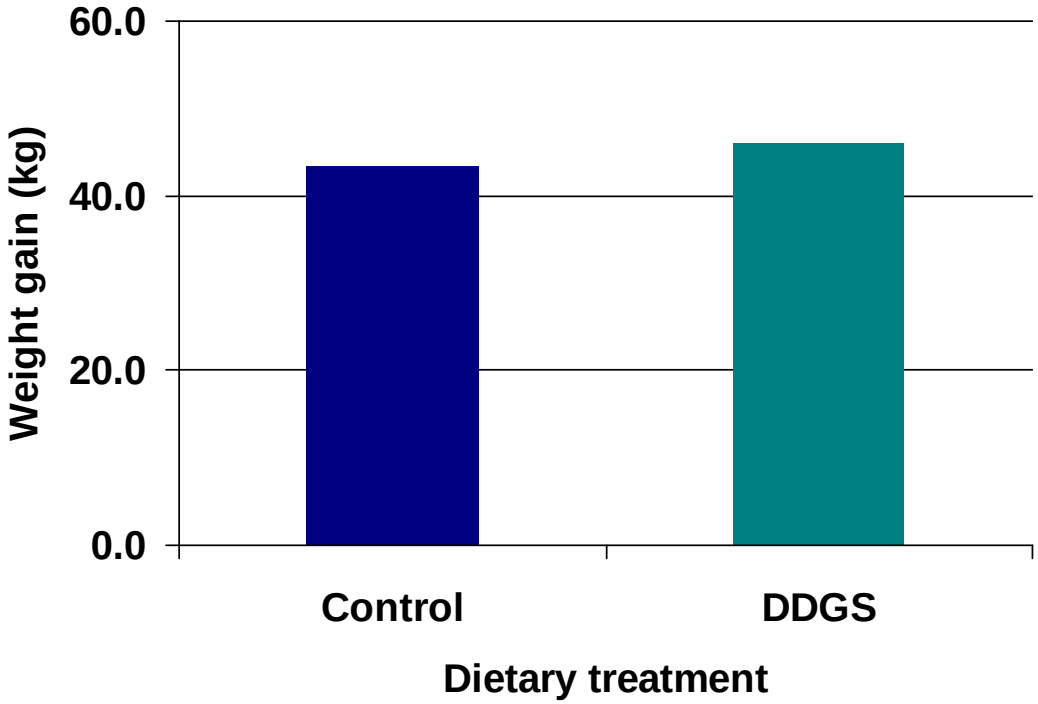


* Effect of disease challenge ($P < .01$).

Feeding High Quality DDGS to Sows

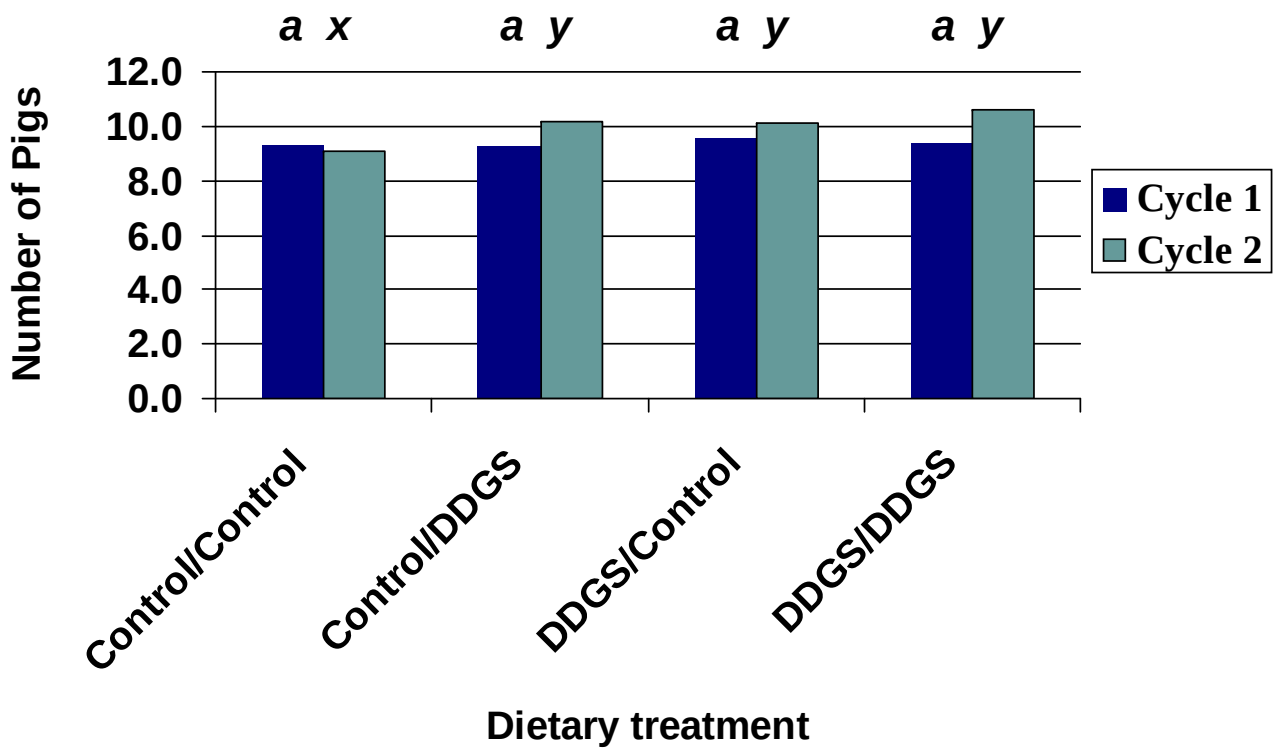


Effect of Feeding a 50% DDGS Diet on Sow Weight Gain During Gestation (Reproductive Cycle 1)



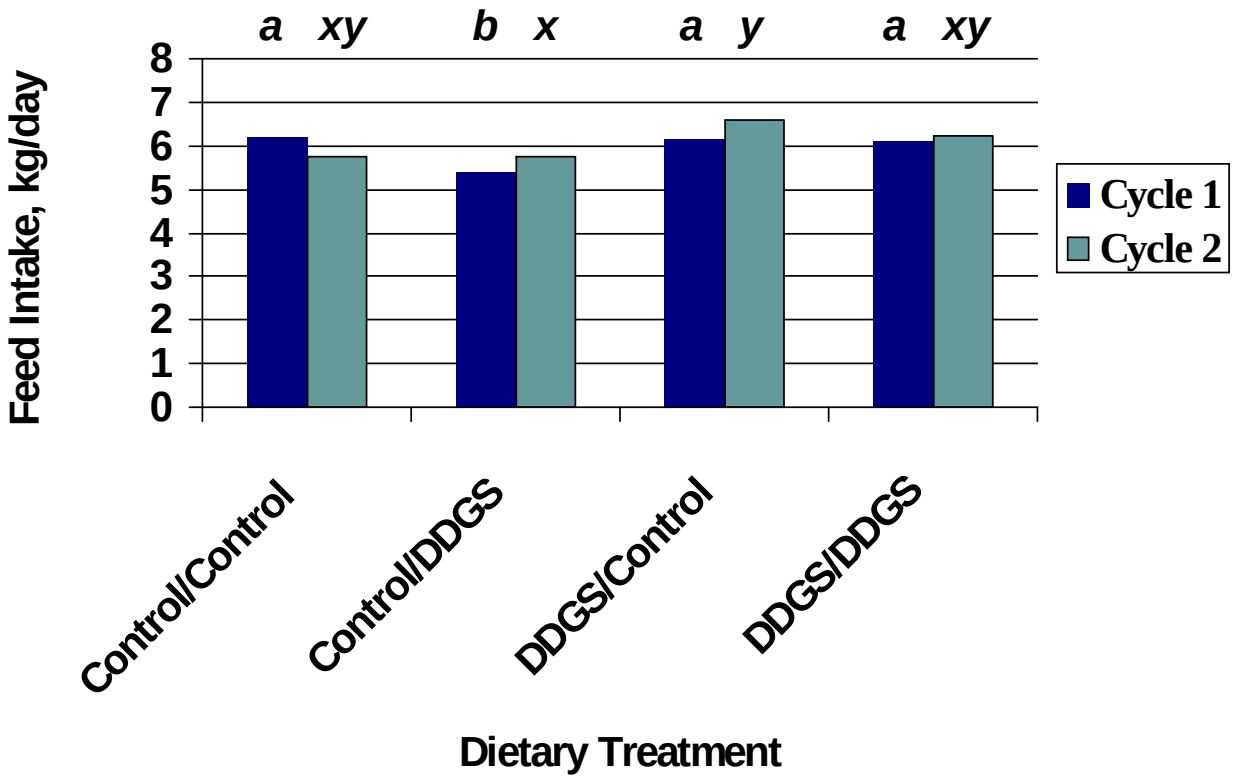
(P > .22)
MSE 10.12

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



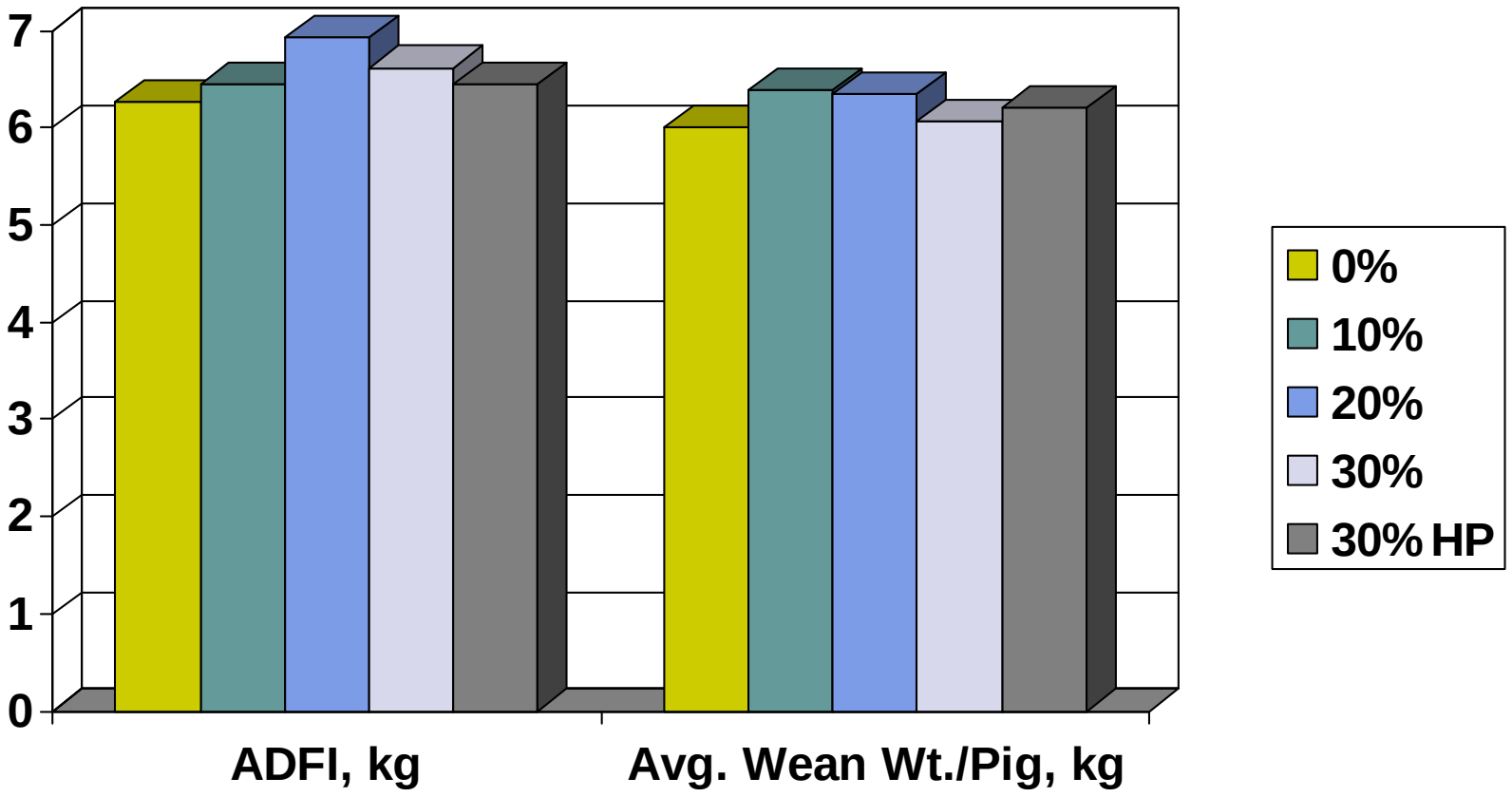
[a,b,x,y] Different superscripts indicate significant difference (P < .10).

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)

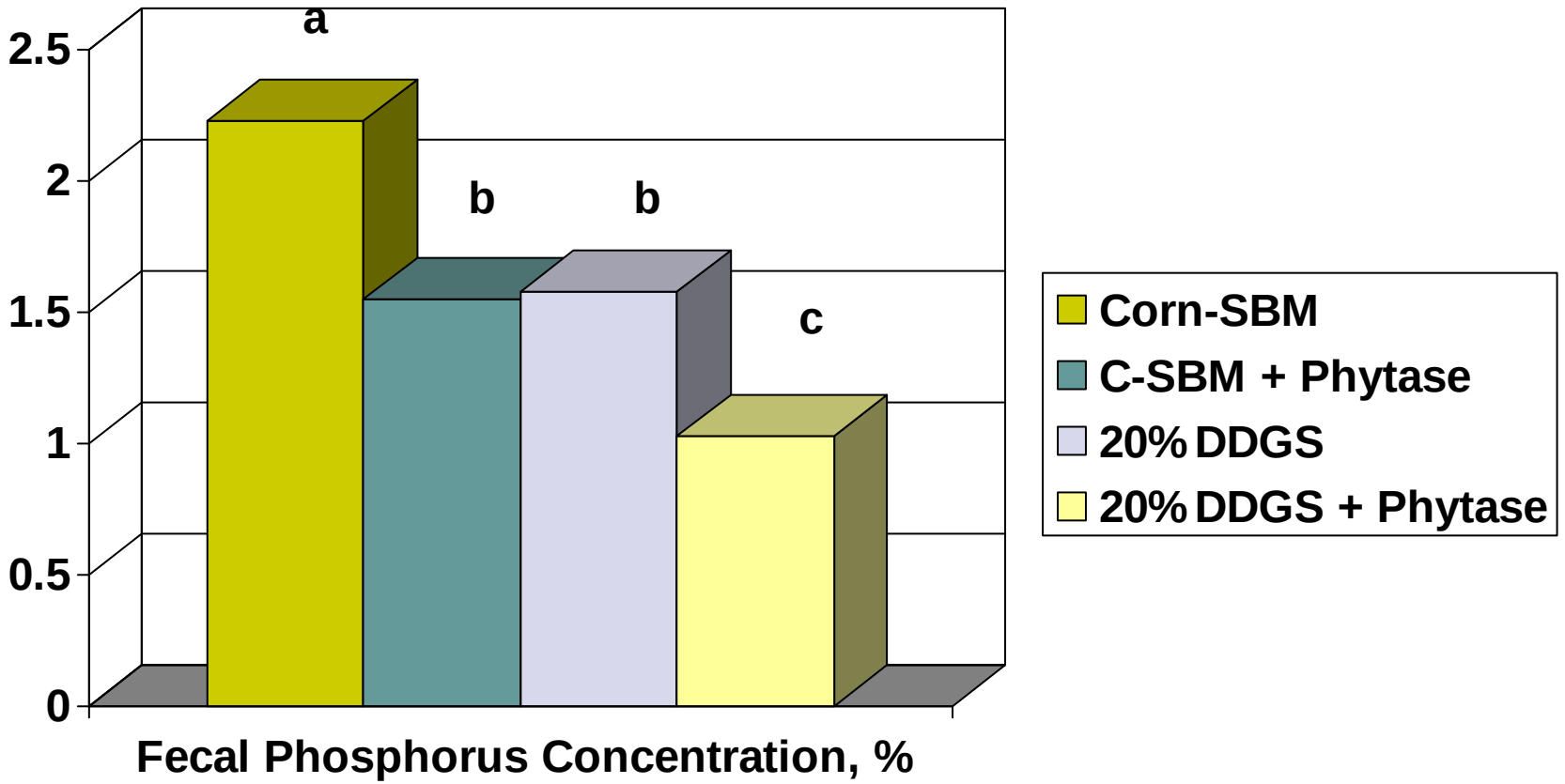


Utilized 323 lactating sows (65 sows/dietary treatment)

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

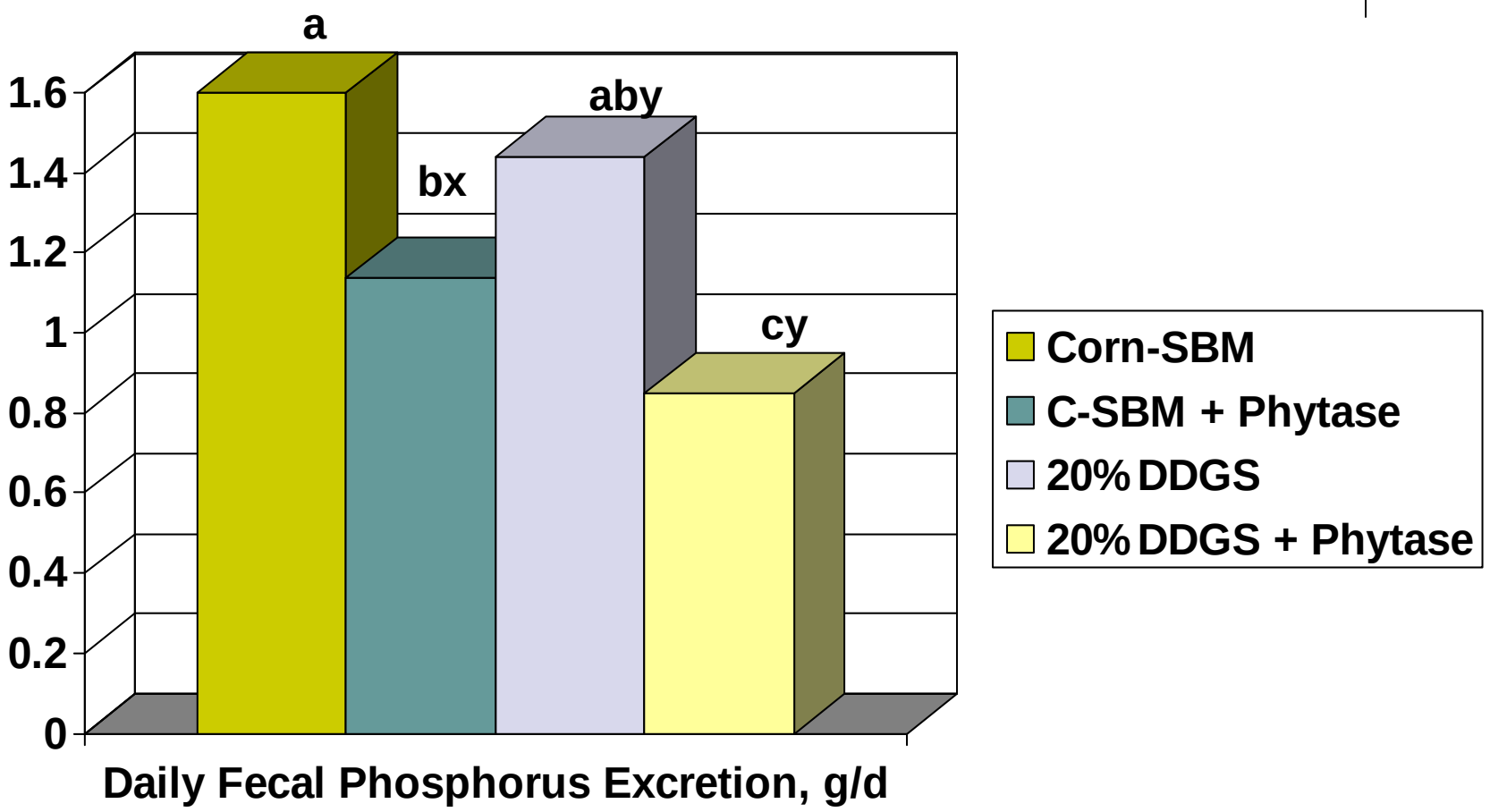
Ingredient	Corn-SBM-1.5 kg Lysine	18.8% DDGS + Phytase
Corn, kg	798.3	636.3
Soybean meal 44%, kg	176.9	159.4
DDGS, kg	0.0	188
Dicalcium phosphate, kg	11.6	0.0
Limestone, kg	7.2	9.8
Salt, kg	3.0	3.0
L-lysine HCl, kg	1.5	1.5
VTM premix, kg	1.5	1.5
Phytase, 500 FTU/kg	0.0	0.5
TOTAL, kg	1000.0	1000.0

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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