

# **Understanding DDGS and Its Application in Swine and Poultry Feeding**

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# Overview of DDGS – Production and Consumption

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# What is DDGS?

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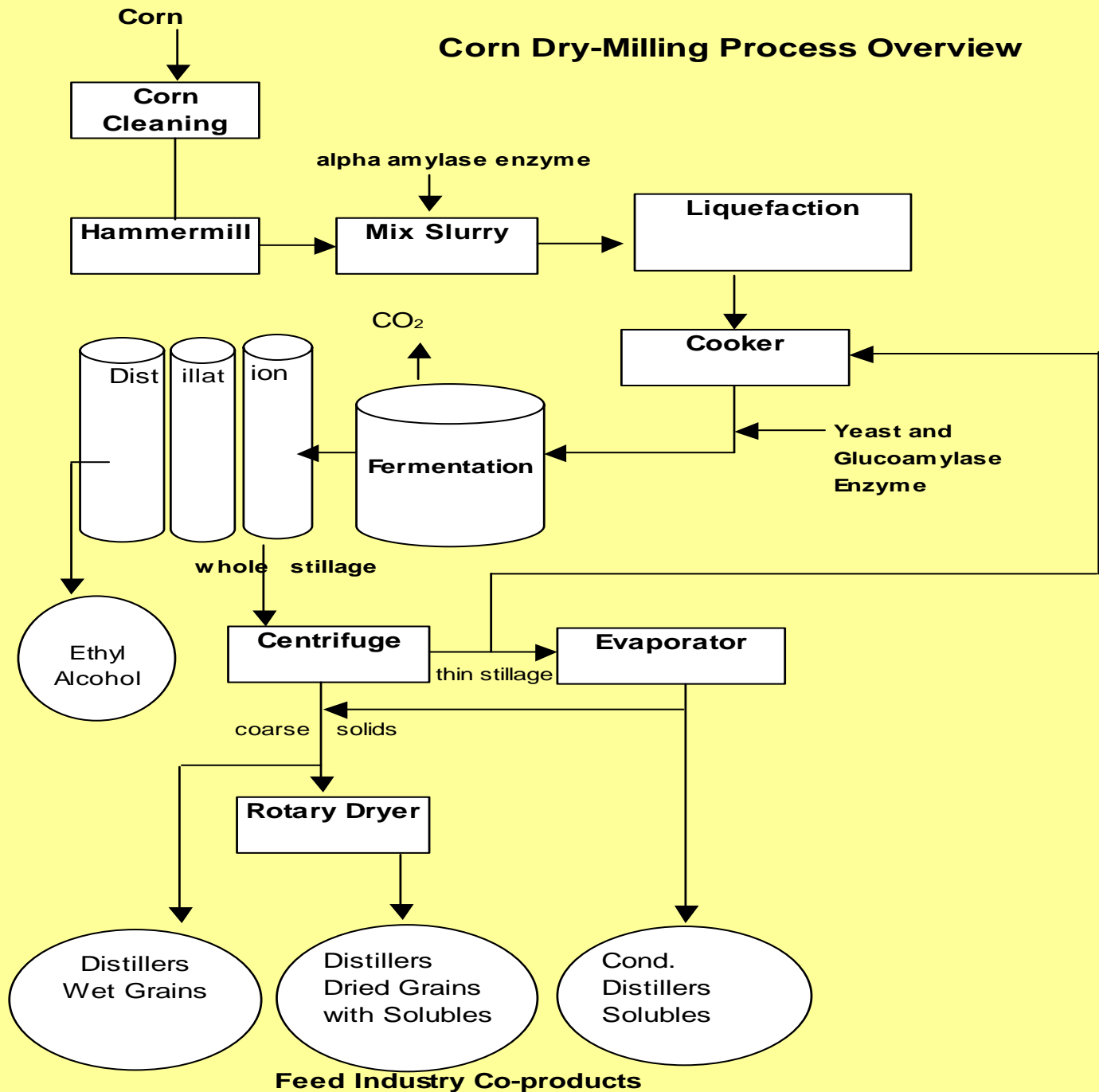
- ❑ **Distiller's dried grains with solubles (DDGS)**
  - By-product of the **dry-grind** ethanol industry
- ❑ Nutrient composition is **different** between dry-grind, wet-mill and beverage alcohol by-products
  - DDGS – fuel ethanol
  - DDGS - whiskey distilleries
  - Corn gluten feed – wet mill
  - Corn gluten meal – wet mill
  - Brewer's dried grains – beer manufacturing
- ❑ Nutrient content depends on the grain source used
  - ❑ **Corn DDGS - Midwestern US**
  - ❑ Wheat DDGS - Canada
  - ❑ Sorghum (milo) DDGS - Great Plains US
  - ❑ Barley DDGS

# By-Products from Dry-Grind Ethanol Plants

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- Distiller's grains
  - Wet – 30 to 35% DM
  - Dry – 90 to 92% DM
  
- Condensed distiller's solubles
  - Wet – 30 to 32% DM (variable)
  - Dry – 99% DM (new spray drying process developed at U of M)
  
- Distiller's dried grains with solubles
  - Wet – 30 to 35% DM
  - Dried – 88 to 90% DM (most common by-product)

## Corn Dry-Milling Process Overview



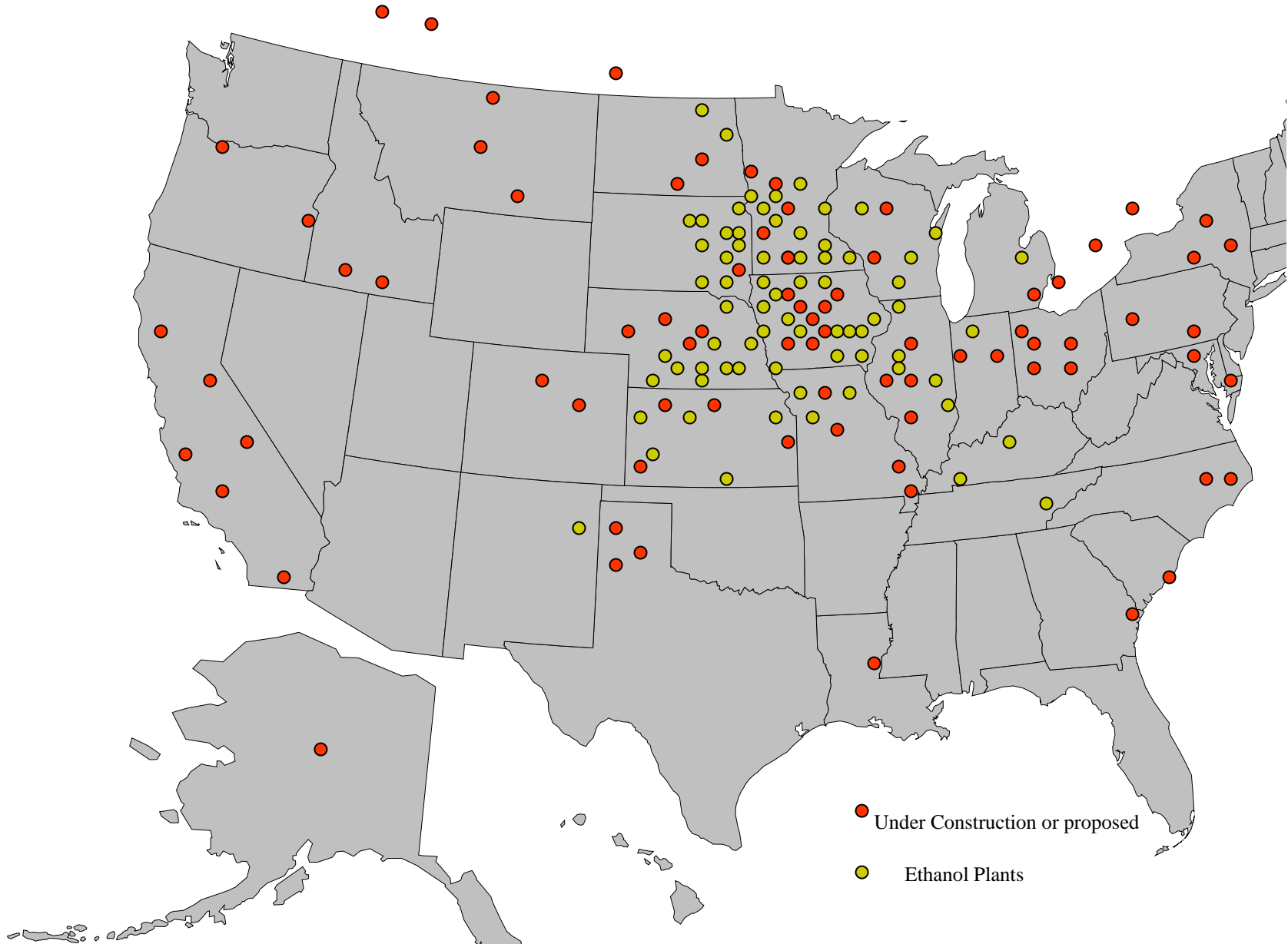
# Dry-Grind Average Ethanol Yield Per Bushel of Corn

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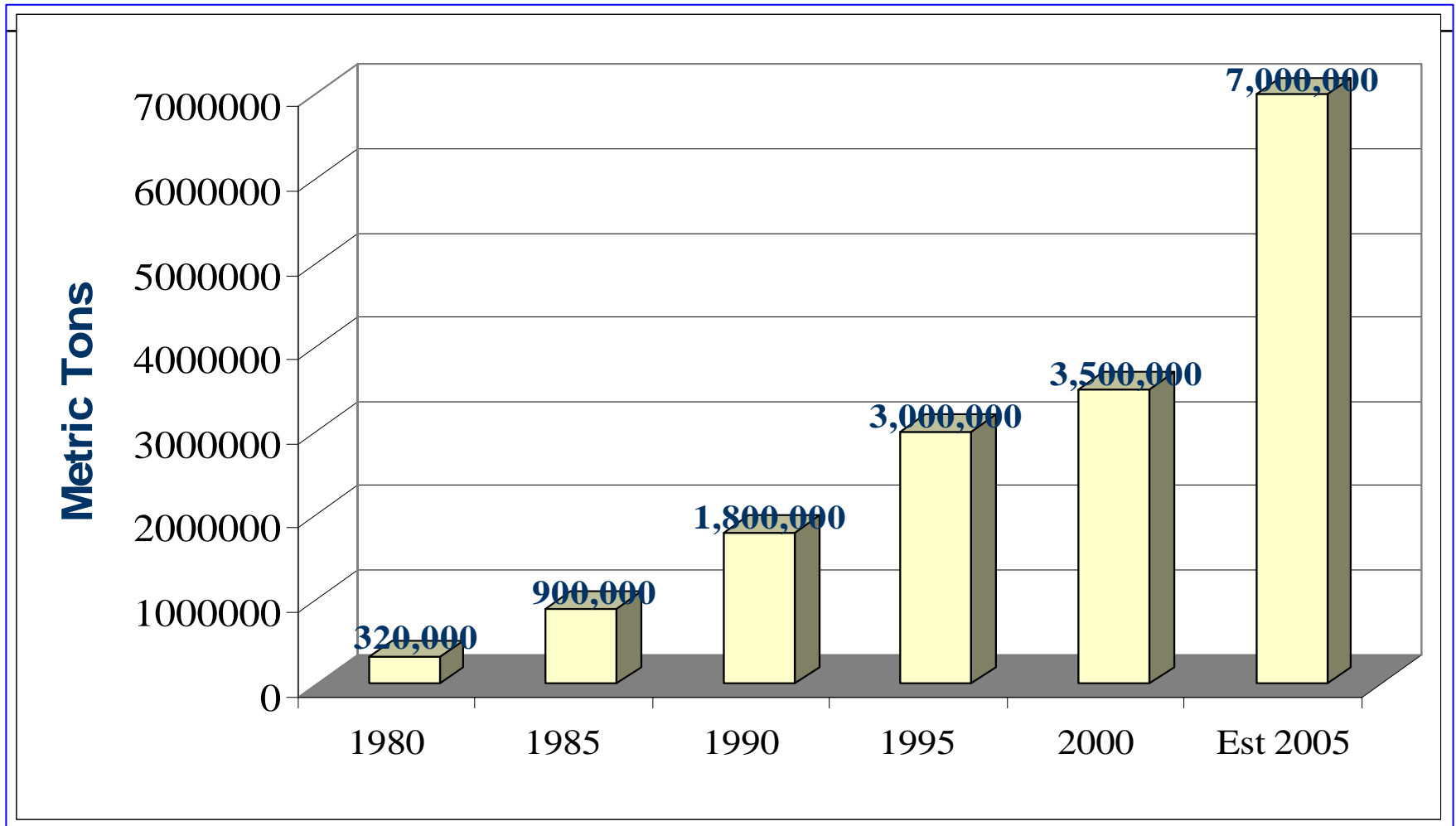


- Ethanol      2.7 gallons
- DDGS        18 lbs
- CO<sub>2</sub>        18 lbs

# Ethanol Plants in North America - June 16, 2004



# U.S. DDGS Production

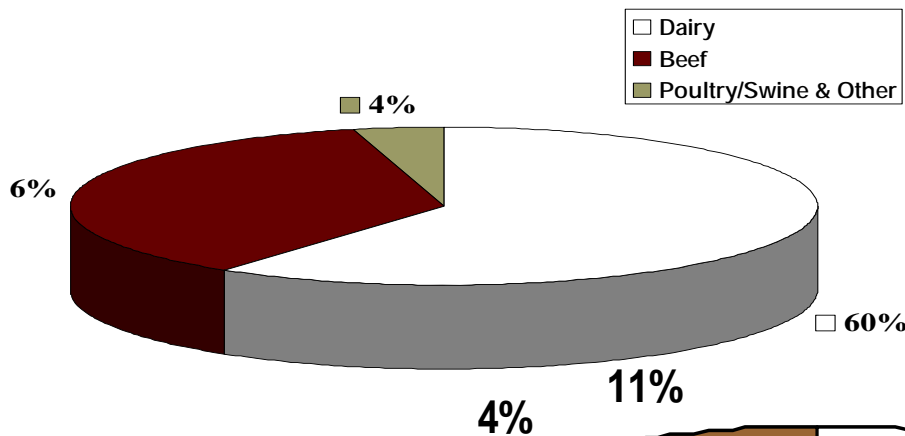


Source: Steve Markham – Commodity Specialists Company

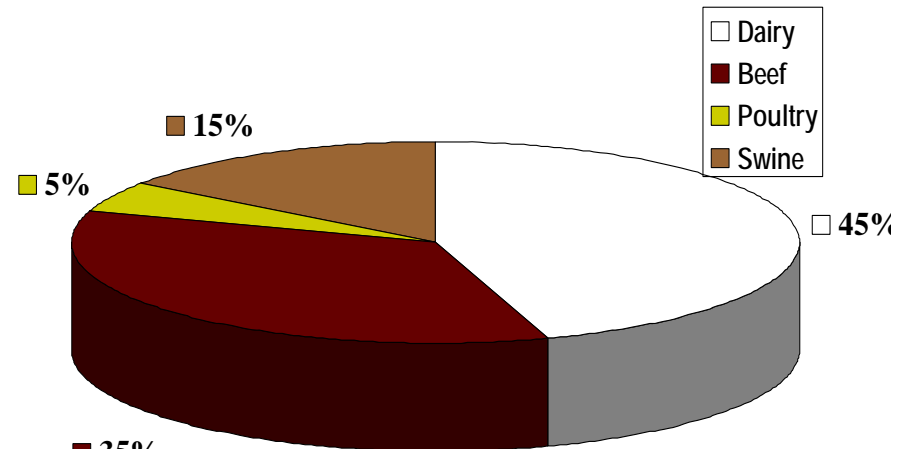


# U.S. DDGS Consumption

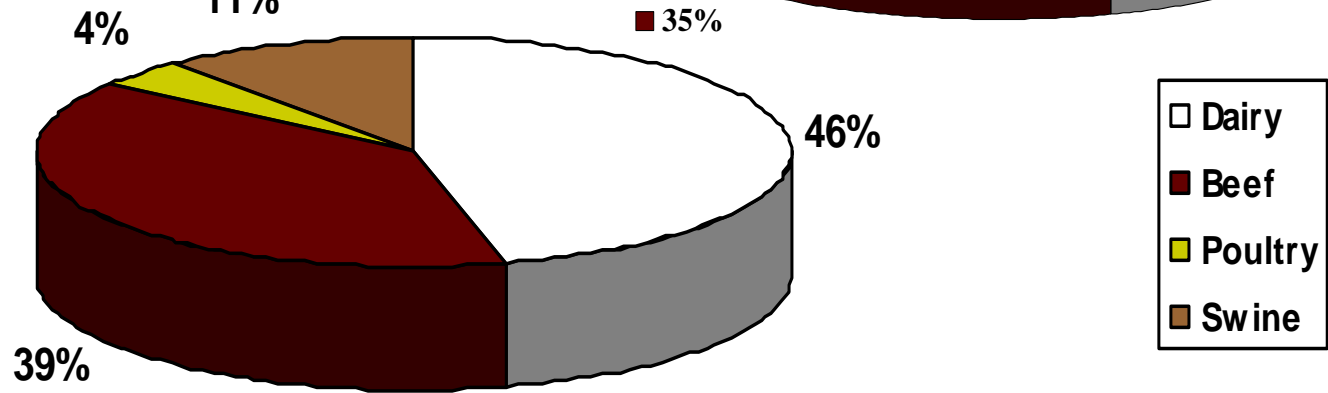
Estimate 2001



Estimate 2002



Estimate 2003



# Comparison of Corn DDGS to Other DDGS Sources and Other Grain By-products

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# Comparison of Nutrient Composition (100% Dry Matter Basis) of Golden DDGS to Corn Gluten Feed, Corn Gluten Meal, Corn Germ Meal, and Brewer's Dried Grains

	“New Generation” 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

# Differences in Quality Characteristics Among U.S. DDGS Sources

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# Color Extremes of DDGS

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

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## **Proximate Analysis and Energy Values Among 27 U.S. DDGS Sources (100% Dry Matter Basis)**

<b>Nutrient</b>	<b>Average</b>	<b>Range</b>
Dry matter, %	89.3	87.3 – 92.4
Crude protein, %	31.0	28.7 – 32.9
Fat, %	10.6	8.8 – 12.4
Fiber, %	7.2	5.4 – 10.4
Ash, %	6.1	3.0 – 9.8
ADF, %	13.6	8.0 – 18.1
Swine DE, kcal/kg	4053	3737 – 4319
Swine ME, kcal/kg	3790	3504 – 4048

## Mineral Analysis Averages and Ranges Among 27 U.S. DDGS Sources (100% Dry Matter Basis)

Nutrient	Average	Range
Ca, %	0.08	0.02 – 0.12
<b>P, %</b>	<b>0.75</b>	<b>0.42 – 0.99</b>
K, %	0.96	0.45 – 1.27
Mg, %	0.29	0.14 – 0.38
S, %	0.62	0.34 – 1.05
Na, %	0.15	0.04 – 0.52
Zn, ppm	62	38 – 105
Mn, ppm	19	9 – 27
Cu, ppm	6	3 – 10
Fe, ppm	133	77 – 239



## Amino Acid Analysis Averages and Ranges Among 27 U.S. DDGS Sources (100% Dry Matter Basis)

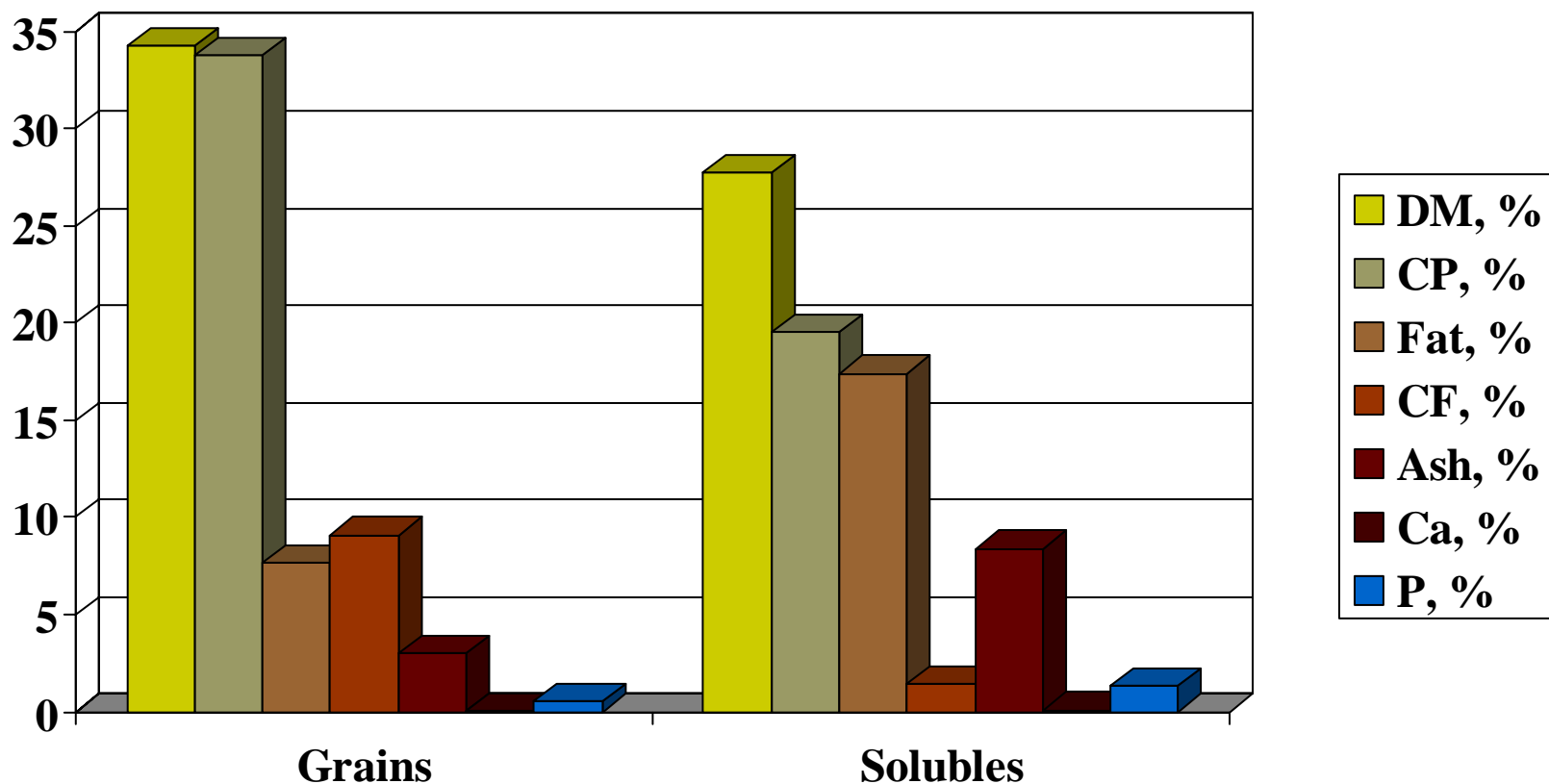
Nutrient	Average	Range
Arg, %	1.31	1.01 – 1.48
His, %	0.84	0.71 – 0.98
Ile, %	1.17	1.01 – 1.31
Leu, %	3.58	2.91 – 3.96
<b>Lys, %</b>	<b>0.89</b>	<b>0.61 – 1.06</b>
<b>Met, %</b>	<b>0.65</b>	<b>0.54 – 0.76</b>
Cys, %	0.68	0.61 – 0.76
Phe, %	1.51	1.36 – 1.72
<b>Thr, %</b>	<b>1.15</b>	<b>1.01 – 1.28</b>
<b>Trp, %</b>	<b>0.25</b>	<b>0.18 – 0.28</b>
Val, %	1.58	1.31 – 1.80

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

	Golden Corn DDGS	Solulac	Badger State Ethanol	ADM - Peoria	Extruded DDGS/Soy (XDS Plus)	AGP Pelleted
Protein, %	31.82	29.32	31.62	30.12	34.44	27.0
Fat, %	11.32	3.52	15.25	8.96	13.33	9.00
Crude fiber, %	6.25	7.90	No data	7.77	7.78	15.10
ADF, %	12.37	11.80	17.91	20.95	14.44	No data
Ash, %	6.93	5.29	4.58	7.30	5.56	4.28
DE, kcal/kg*	4053	3808	No data	3796	No data	No data
ME, kcal/kg*	3781	3577	No data	3560	3749	No data
Lys, %	0.92	0.61	0.90	0.83	1.67	No data
Met, %	0.62	0.54	0.54	0.66	0.61	No data
Thr, %	1.17	1.01	1.04	1.13	2.50	No data
Trp, %	0.25	0.18	0.23	0.25	0.39	No data
Ca, %	0.07	0.12	0.06	0.51	0.22	0.17
P, %	0.77	0.78	0.89	0.68	0.72	0.62

\*Calculated energy values for swine

# Comparison of the Nutrient Content of Corn Distiller's Grains and Corn Condensed Distiller's Solubles



# Samples of Golden Corn DDGS from Various Midwestern U.S. Ethanol Plants

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**VeraSun - Aurora, SD**



**CVEC - Benson, MN**



**Al-Corn - Claremont, MN**



**MGP - Lakota, IA**



**CMEC - Little Falls, MN**



**Agri-Energy - Luverne, MN**

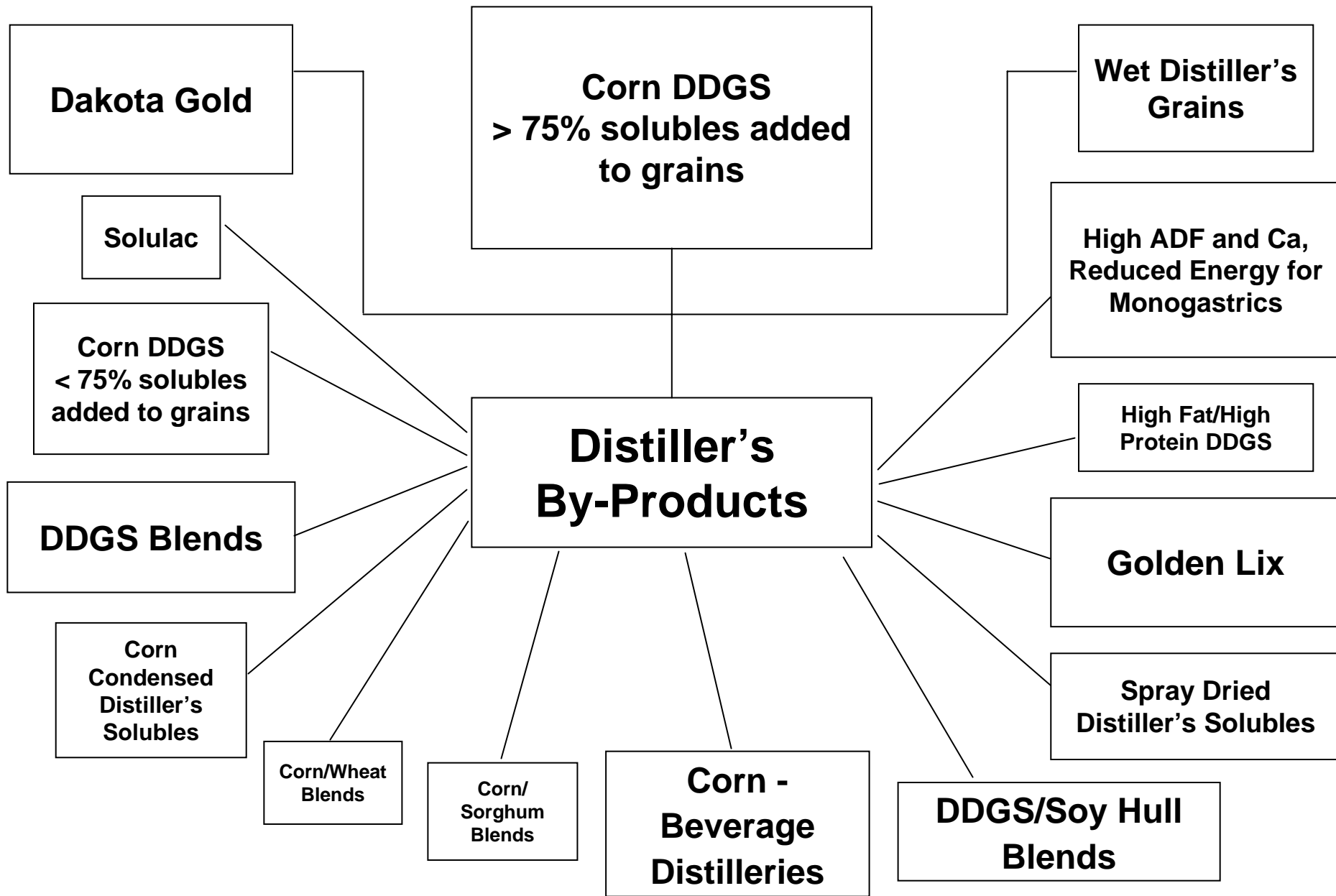


**LSCP - Marcus, IA**



**DENCO - Morris, MN**

# Potential Categories of Distiller's By-Products



# Relative Value of DDGS Differs Depending on Species

## Assumptions:

- Corn                      \$2.00 / bu
- SBM                      \$175.00 / ton
- Urea                      \$360.00 / ton
- Non-ruminant diets corn/SBM
- Ruminant diets typical diets with competing by-products.

## Feed

## Dollars/ ton

Dairy Lactation	\$114.24
Poultry Finisher	\$100.09
Layer Diet	\$104.66
Swine G-F Diet	\$96.34
Beef Feedlot	\$108.00

Source: Tilstra, Land O' Lakes



# Quality Assessment of “New Generation” DDGS

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- ❑ Smell
- ❑ Color
- ❑ Bulk density
- ❑ Particle size
- ❑ Mycotoxins
- ❑ Fat stability

# Corn DDGS Color and Smell are Indicators of Digestibility for Monogastrics

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## □ Color varies among sources

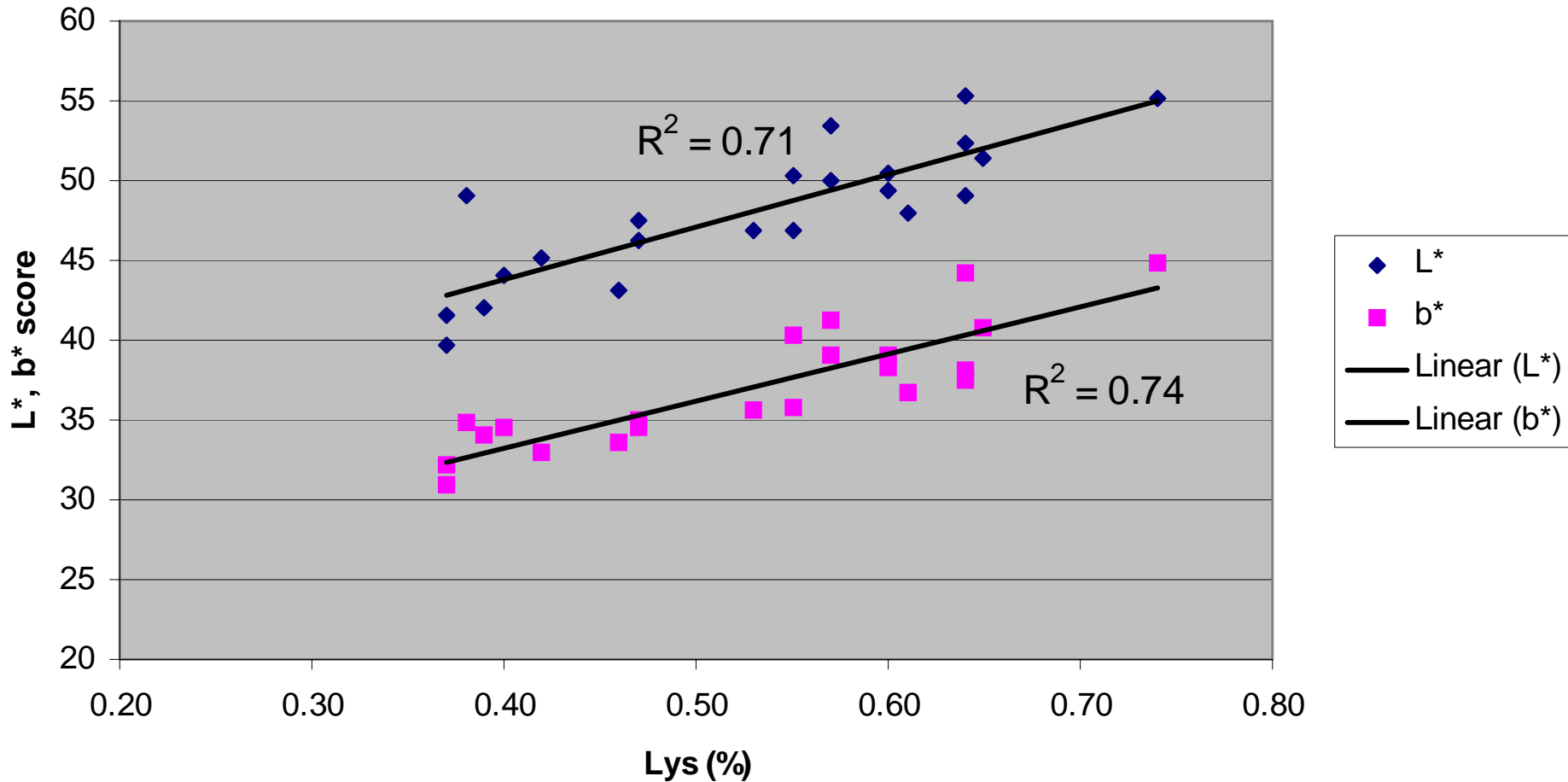
- ranges from dark to golden (Cromwell et al., 1993)
- golden color of corn DDGS is correlated with higher amino acid digestibility in swine and poultry

## □ Smell varies among sources

- ranges from burnt or smoky to sweet and fermented (Cromwell et al., 1993)
- golden DDGS has a sweet, fermented smell
- smell may affect palatability

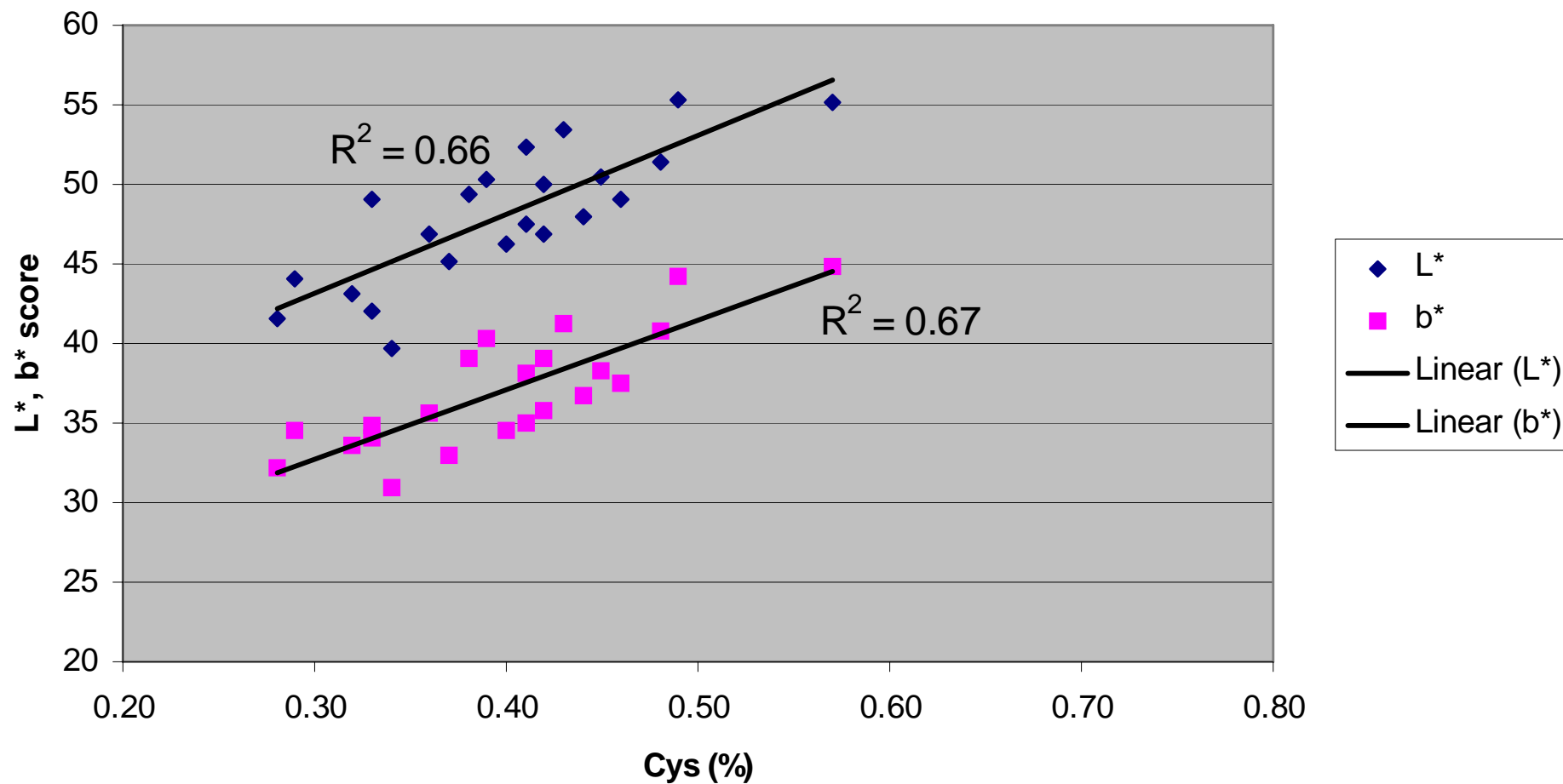


**Fig. 1. Regression of digestible lys (%) and color (L\*, b\*)**



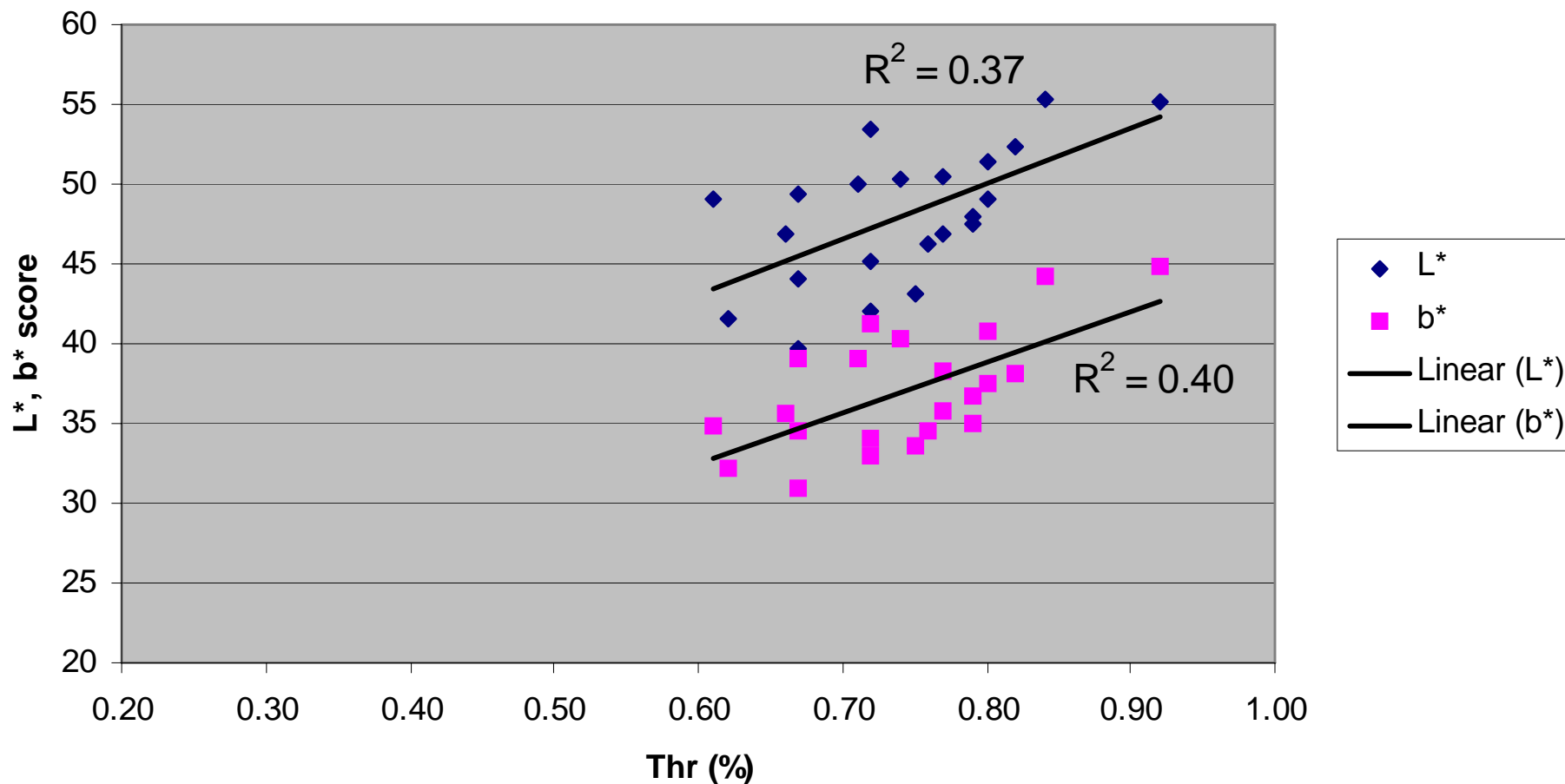
Source: Dr. Sally Noll (2003)

**Fig. 2. Regression of digestible cys (%) and color (L\*, b\*)**



Source: Dr. Sally Noll (2003)

**Fig. 3. Regression of digestible thr (%) and color (L\*, b\*)**



Source: Dr. Sally Noll (2003)

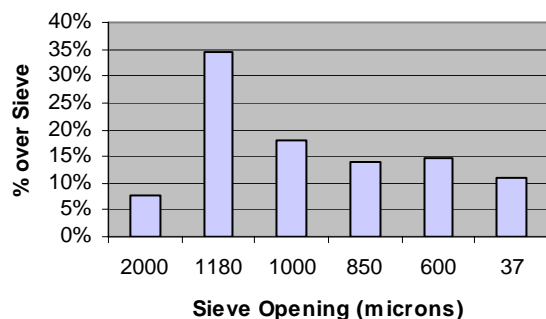
# Physical Characteristics of “New Generation” DDGS

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- Bulk density (16 new plants)
  - $35.7 \pm 2.79$  lbs/ft<sup>3</sup>
  - Range 30.8 to 39.3 lbs/ft<sup>3</sup>
  
- Particle size (16 new plants)
  - $1282 \pm 305$  microns
  - Range 612 to 2125 microns

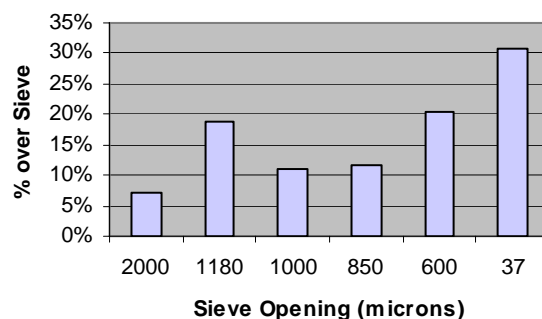
# Examples of Particle Size Distribution of “New Generation” DDGS

Plant 7 Particle Size Analysis



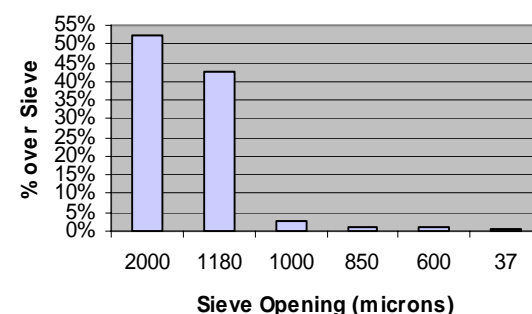
Typical

Plant 6 Particle Size Analysis



Lowest Avg.  
Particle Size

Plant 15 Particle Size Analysis



Highest Avg.  
Particle Size

# Mycotoxins

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- Incidence of mycotoxin contamination of DDGS from upper Midwest ethanol plants is low
  - Poor quality corn = poor ethanol yields
  - Corn supplied from a relatively small geographic region
  - Corn produced in upper Midwest is generally lower risk for mycotoxins
- Must use thin layer chromatography (TLC) or HPLC for analyzing DDGS
  - ELISA and other methods result in false positives



# Fat Stability of DDGS

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- Limited data
- Mexico
  - DDGS monitored during transit and storage for 16 weeks in a commercial feed mill in Jalisco, Mexico
    - Temperature ranged from 2 to 28 degrees C
    - Average high temperature 25 degrees C
    - Average low temperature was 8.4 degrees C
  - No rancidity was detectable



# Fat Stability of DDGS in Taiwan

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- ❑ Study conducted at Lin-Fong-Ying Dairy Farm
  - ❑ a commercial dairy farm located about 20 km south of the Tropic of Cancer
  - ❑ DDGS was shipped from Watertown, SD to Taiwan in a 40 ft. container
  - ❑ upon arrival in Taiwan, DDGS was re-packaged in 50 kg feed bags with a plastic lining
  - ❑ DDGS bags were stored in a covered steel pole barn for 10 weeks during the course of the dairy feeding trial



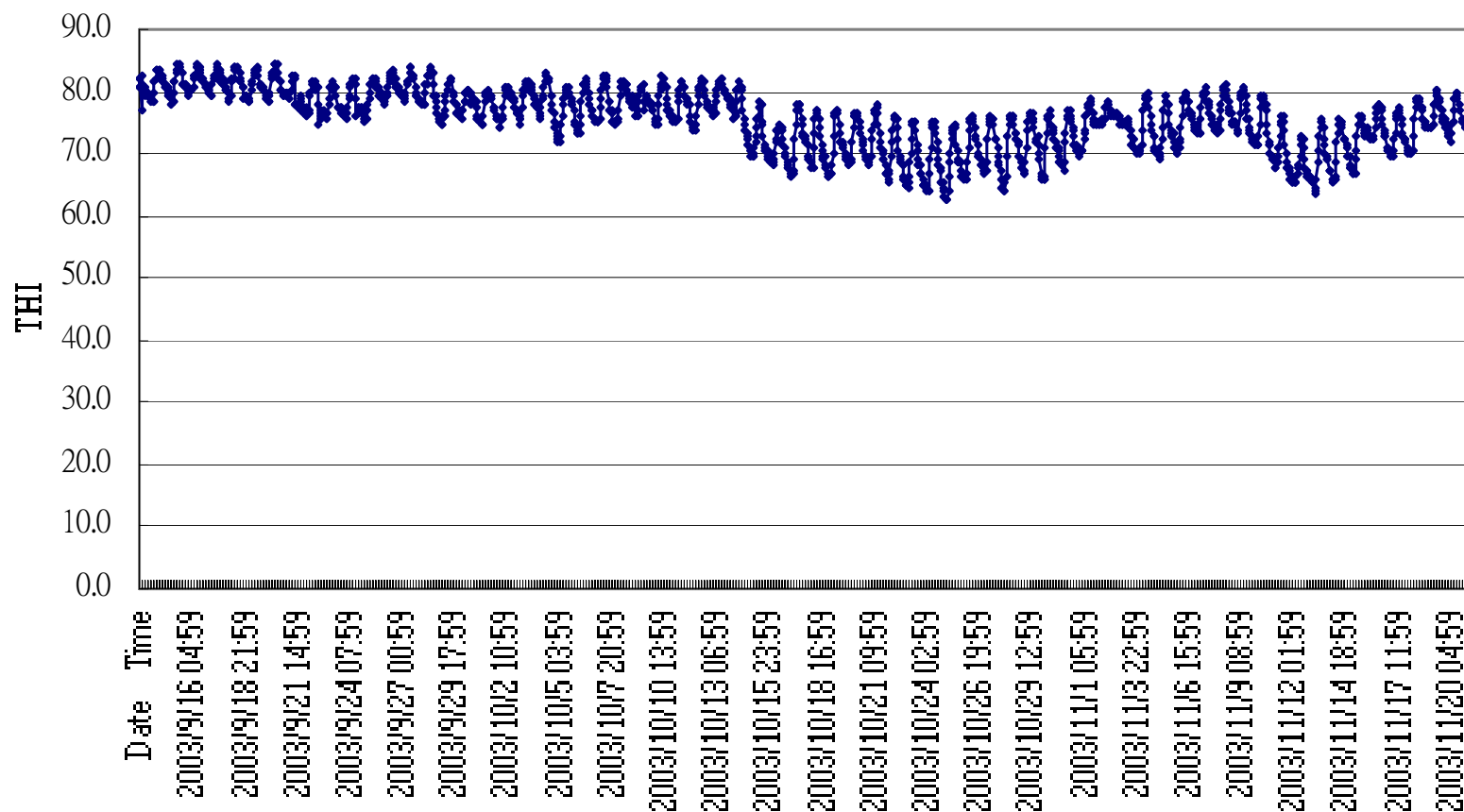


**Dr. Yuan-Kuo Chen discussing DDGS sampling procedures from storage bags with his research assistant.**



**Inside of the covered, steel pole barn used to store bags of DDGS and other forage and feed ingredients at LFY Dairy.**

# Temperature-Humidity-Index (THI) During the Taiwan DDGS Fat Stability Trial



# 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.**

# Feeding Value of DDGS for Swine

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# Comparison of Energy Values of DDGS for Swine (88% DM Basis)

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	“New” DDGS Calculated U of M	“New” DDGS Trial avg. U of M	DDGS Calculated U of M	DDGS NRC (1998)
DE, kcal/kg	3488 Range 3418-3537	3528 Range 2975-4086	3409	3449
ME, kcal/kg	3162 Range 3087-3215	3367 Range 2820-3916	3098	2672

Corn (NRC, 1998):      DE (kcal/kg) = 3484  
                                 ME (kcal/kg) = 3382

# Comparison of DE and ME Estimates of DDGS for Swine (88% DM)

	DE, Mcal/kg	ME, Mcal/kg	NE, Mcal/kg
U of M – Golden DDGS (1999)	3.49	3.37	No data
U of M – Traditional (1999) <sup>1</sup>	3.41	3.10	No data
KSU – New Generation (2004) <sup>2</sup>	3.87	3.49 – 3.70	2.61
KSU – “Old Generation” (2004) <sup>3</sup>	3.73	3.13 – 3.59	2.45
Hanor-Hubbard-Ajinomoto (2004) <sup>4</sup>	No data	3.25	2.42
NRC (1998)	3.45	2.67	No data

<sup>1</sup> Calculated values

<sup>2</sup> Determined by growth and metabolism trials (source Dakota Gold)

<sup>3</sup> Not DDGS but corn gluten from a NE ethanol plant

<sup>4</sup> Determined by growth trials (source Dakota Gold)

# Comparison of Amino Acid Composition of DDGS (88% dry matter basis)

	Golden DDGS	Traditional DDGS	DDGS (NRC, 1998)
Lysine, %	0.75 (17.3)	0.47 (26.5)	0.59
Methionine, %	0.63 (13.6)	0.44 (4.5)	0.48
Threonine, %	0.99 (6.4)	0.86 (7.3)	0.89
Tryptophan, %	0.22 (6.7)	0.17 (19.8)	0.24
Valine, %	1.32 (7.2)	1.22 (2.3)	1.23
Arginine, %	1.06 (9.1)	0.81 (18.7)	1.07
Histidine, %	0.67 (7.8)	0.54 (15.2)	0.65
Leucine, %	3.12 (6.4)	2.61 (12.4)	2.43
Isoleucine, %	0.99 (8.7)	0.88 (9.1)	0.98
Phenylalanine, %	1.29 (6.6)	1.12 (8.1)	1.27

Values in ( ) are CV's among plants

## Comparison of Apparent Ileal Digestible Amino Acid Composition of DDGS for Swine (88% dry matter basis)

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	<b>Golden DDGS</b>	<b>Traditional DDGS</b>	<b>DDGS (NRC, 1998)</b>
Lysine, %	0.39	0.00	0.27
Methionine, %	0.28	0.21	0.34
Threonine, %	0.55	0.32	0.49
Tryptophan, %	0.13	0.13	0.12
Valine, %	0.81	0.45	0.77
Arginine, %	0.79	0.53	0.77
Histidine, %	0.45	0.26	0.40
Leucine, %	2.26	1.62	1.85
Isoleucine, %	0.63	0.37	0.64
Phenylalanine, %	0.78	0.60	0.96



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

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	<b>Golden DDGS</b>	<b>Traditional DDGS</b>	<b>DDGS NRC (1998)</b>	<b>Corn NRC (1998)</b>
<b>Total P, %</b>	0.78 Range 0.62-0.87	0.79	0.73	0.25
<b>P Availability, %</b>	90 Range 88-92	No data	77	14
<b>Available P, %</b>	0.70	No data	0.56	0.03

# Why is there so much interest in feeding DDGS to swine?

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- Golden DDGS is high in digestible nutrients
- Economical partial replacement for:
  - corn
  - soybean meal
  - dicalcium phosphate
- Increasing production and supply
- Unique properties
  - reduce P excretion in manure
  - increase litter size weaned/sow
  - gut health benefits

# Maximum Inclusion Rates of “New Generation” DDGS in Swine Diets

(Based Upon University of Minnesota Performance Trials)

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- Nursery pigs (> 7 kg)
  - Up to 25 %
- Grow-finish pigs
  - Up to 20% (higher levels may reduce pork fat quality)
- Gestating sows
  - Up to 50%
- Lactating sows
  - Up to 20%

Assumptions: no mycotoxins

formulate on a digestible amino acid and available phosphorus basis

# Feeding Golden DDGS to Weaned Pigs

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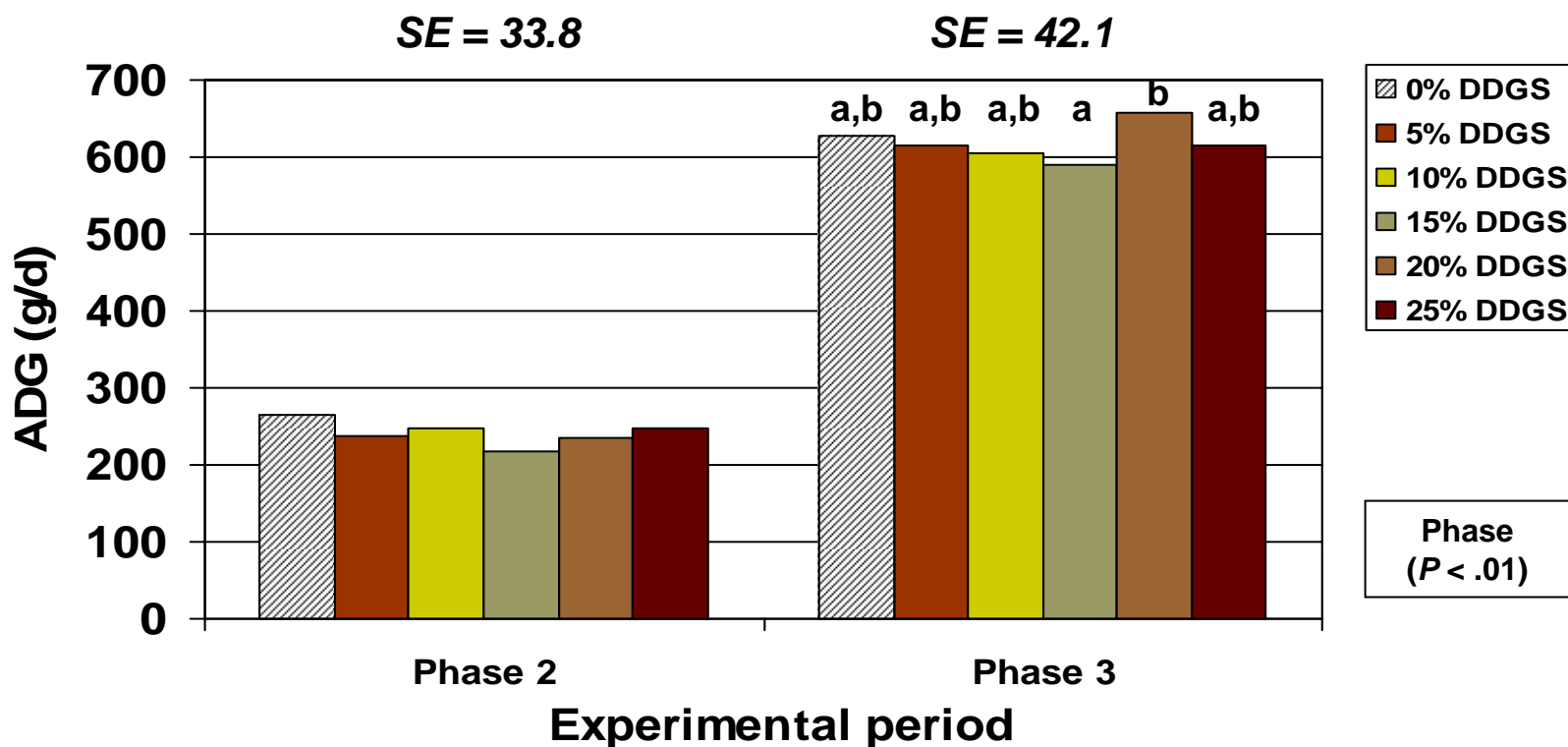


# Materials and Methods – Nursery Experiments

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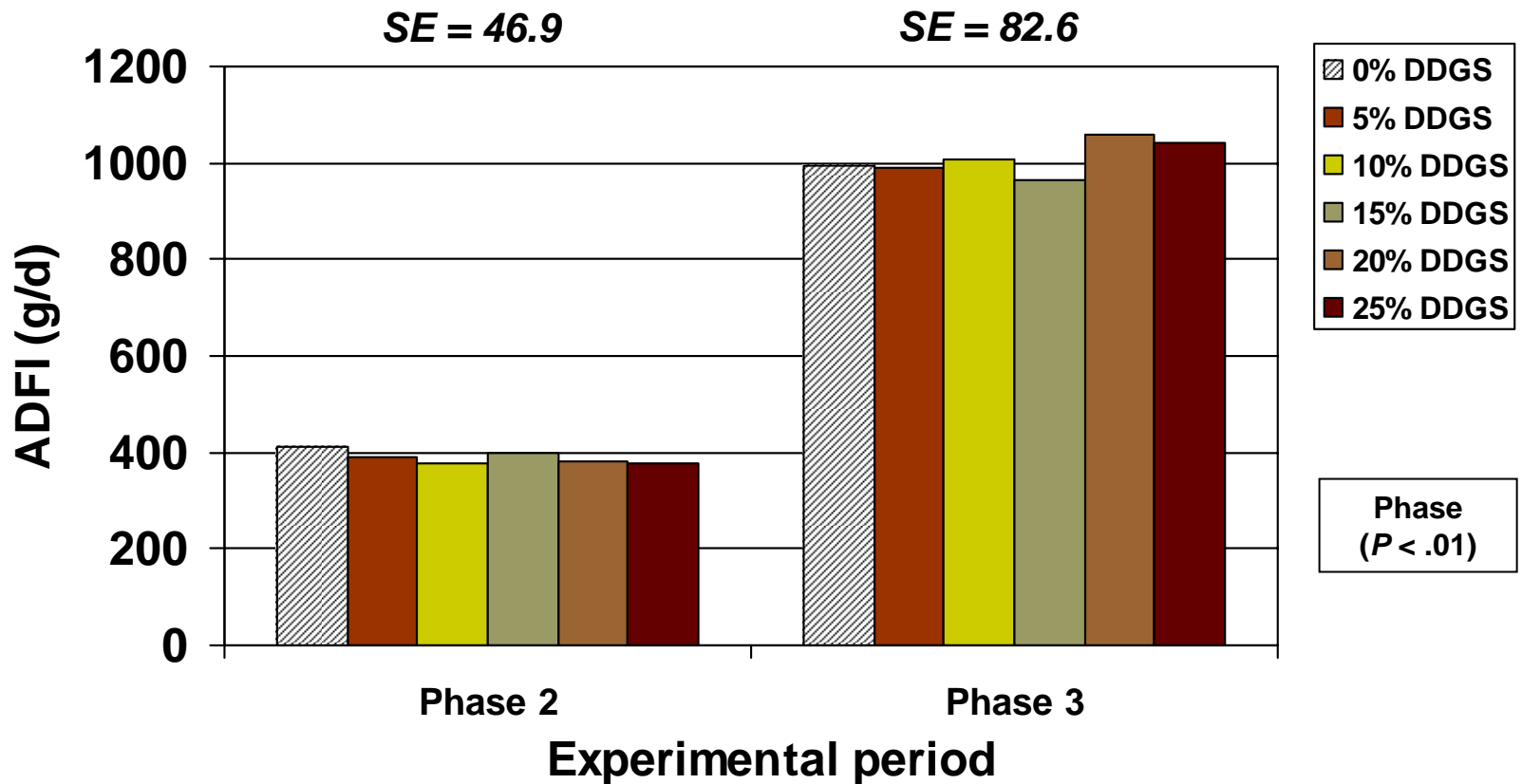
- Experiment 1
  - Pigs weaned at  $19.0 \pm 0.3$  d of age
  - Weighed  $7.10 \pm 0.07$  kg
- Experiment 2
  - Pigs weaned at  $16.9 \pm 0.4$  d of age
  - Weighed  $5.26 \pm 0.07$  kg
- Pigs were fed a commercial pelleted diet (d 0 to 3 postweaning)
- Phase II (d 4-17) and Phase III (d 18 – 35) diets were **formulated on a digestible amino acid basis.**
  - Diets contained 0, 5, 10, 15, 20, or 25% DDGS

# Effect of DDGS Level on Growth Rate (Experiment 1)

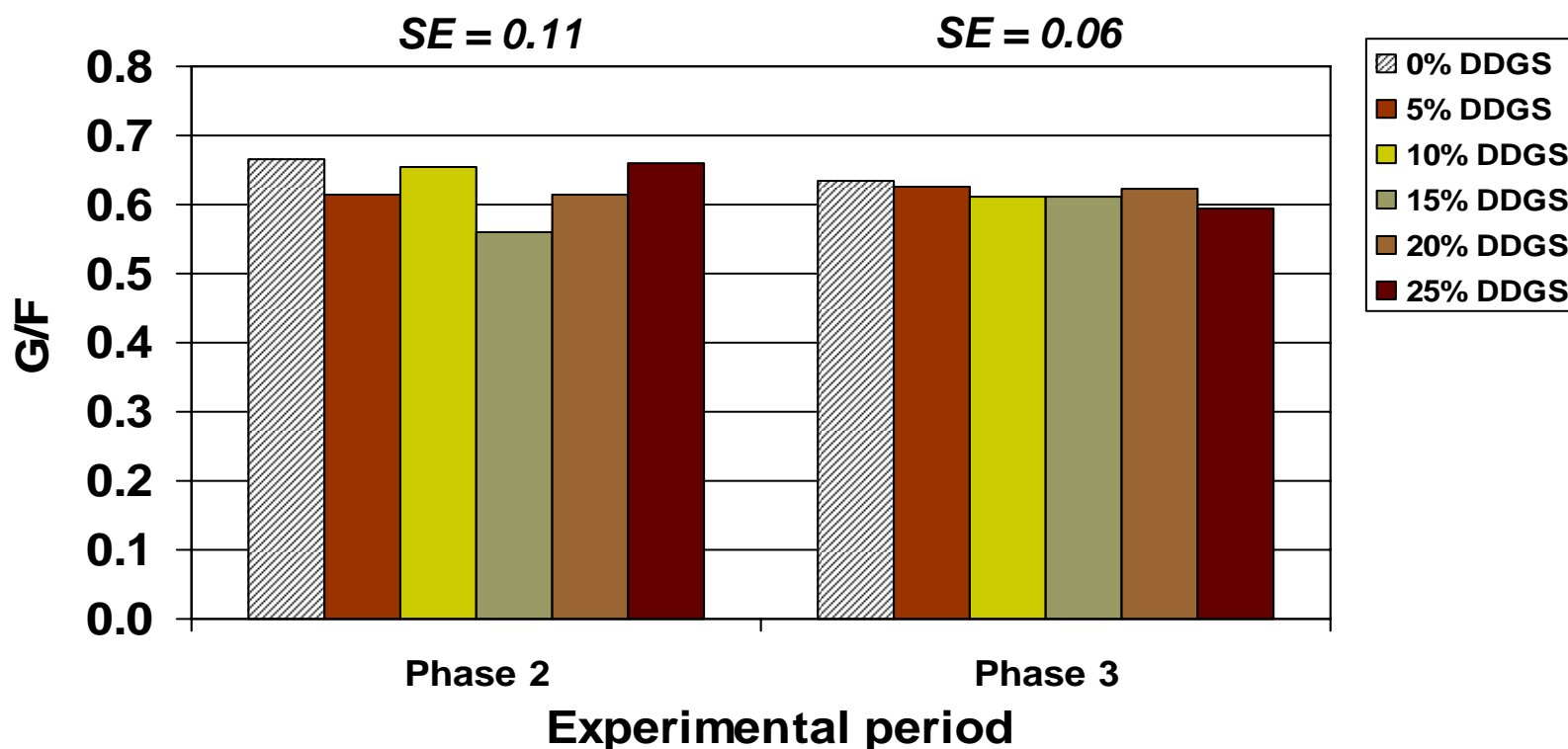


Means not sharing a common superscript letter are significantly different ( $P < .05$ )

# Effect of DDGS Level on ADFI (Experiment 1)

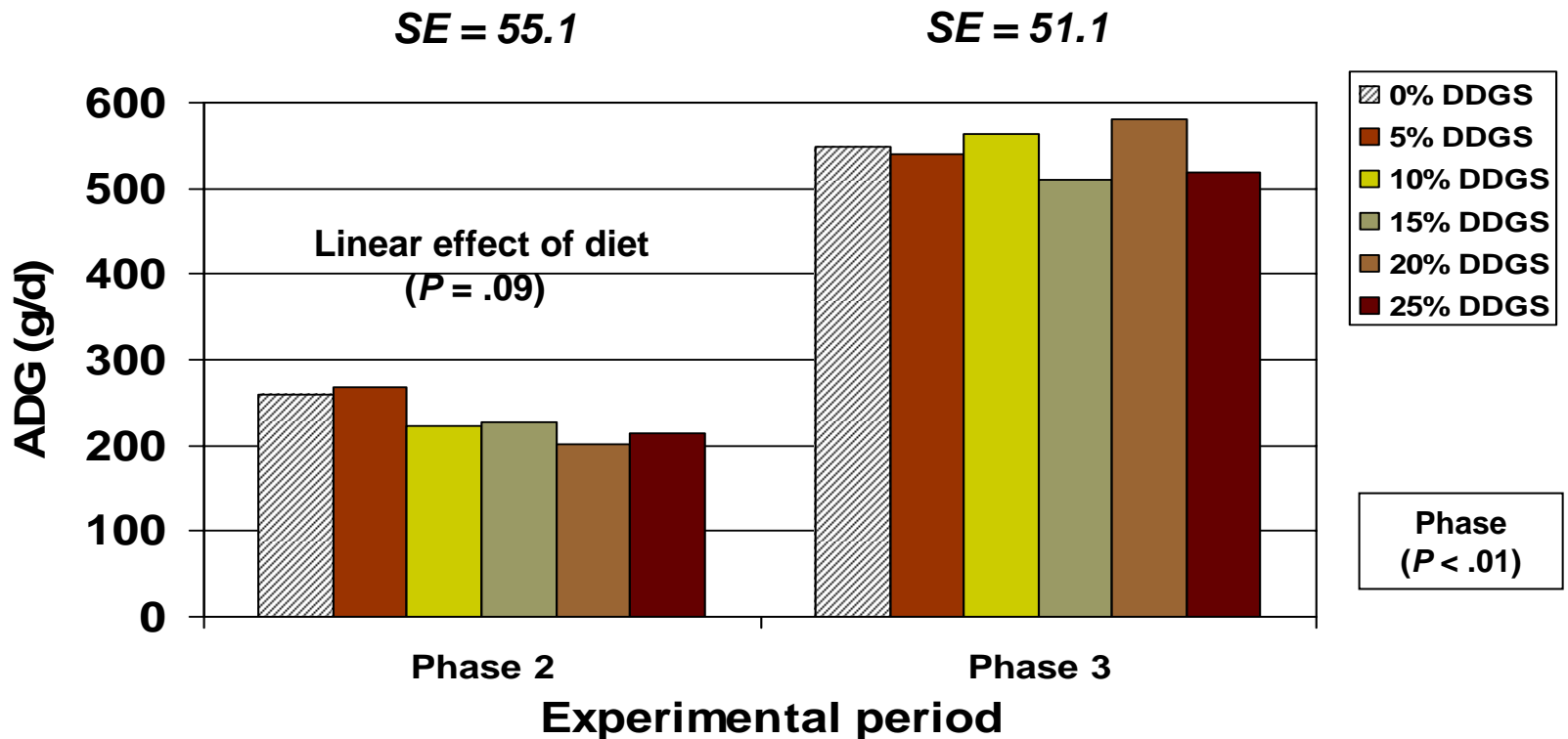


# Effect of DDGS Level on Gain/Feed (Experiment 1)

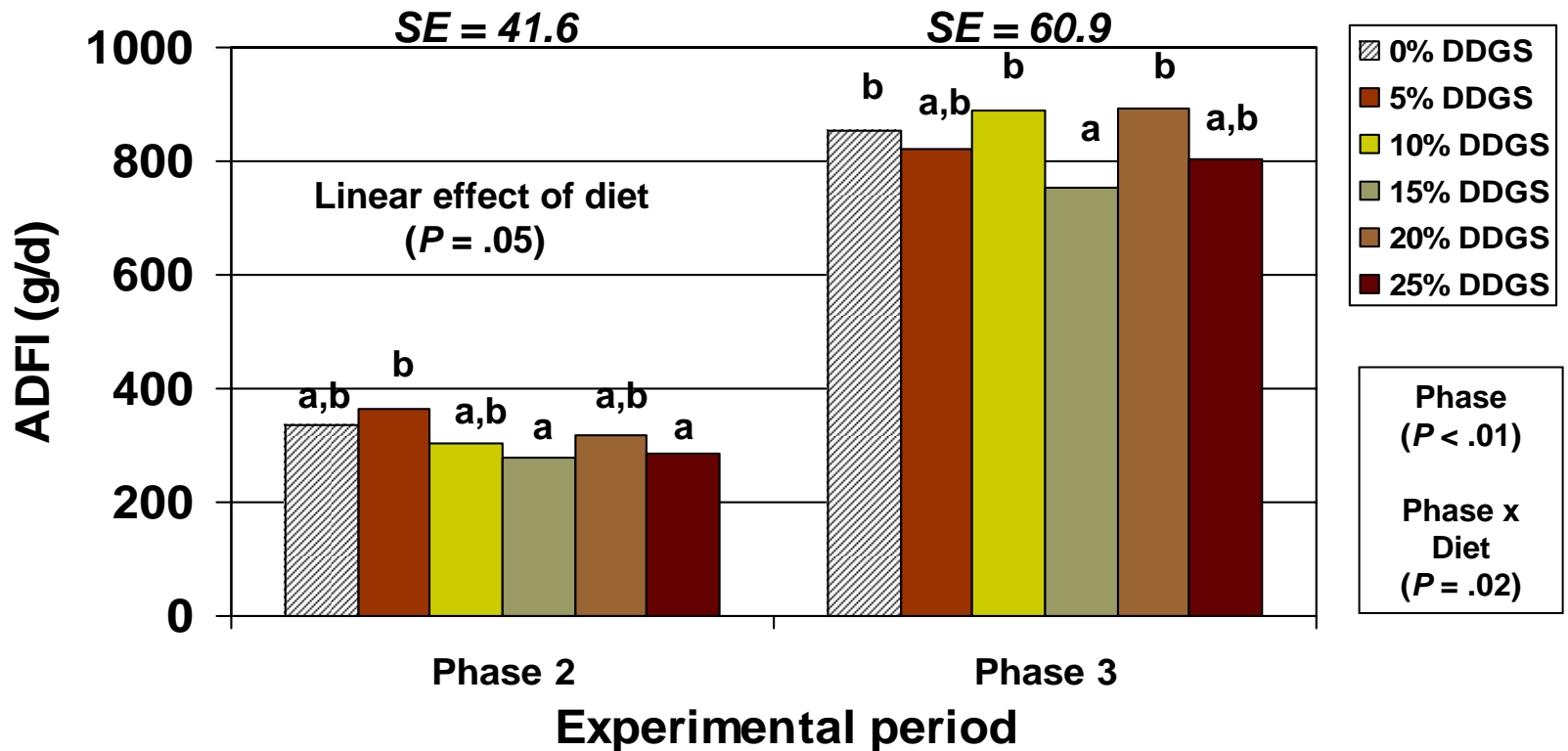




# Effect of DDGS Level on Growth Rate (Experiment 2)

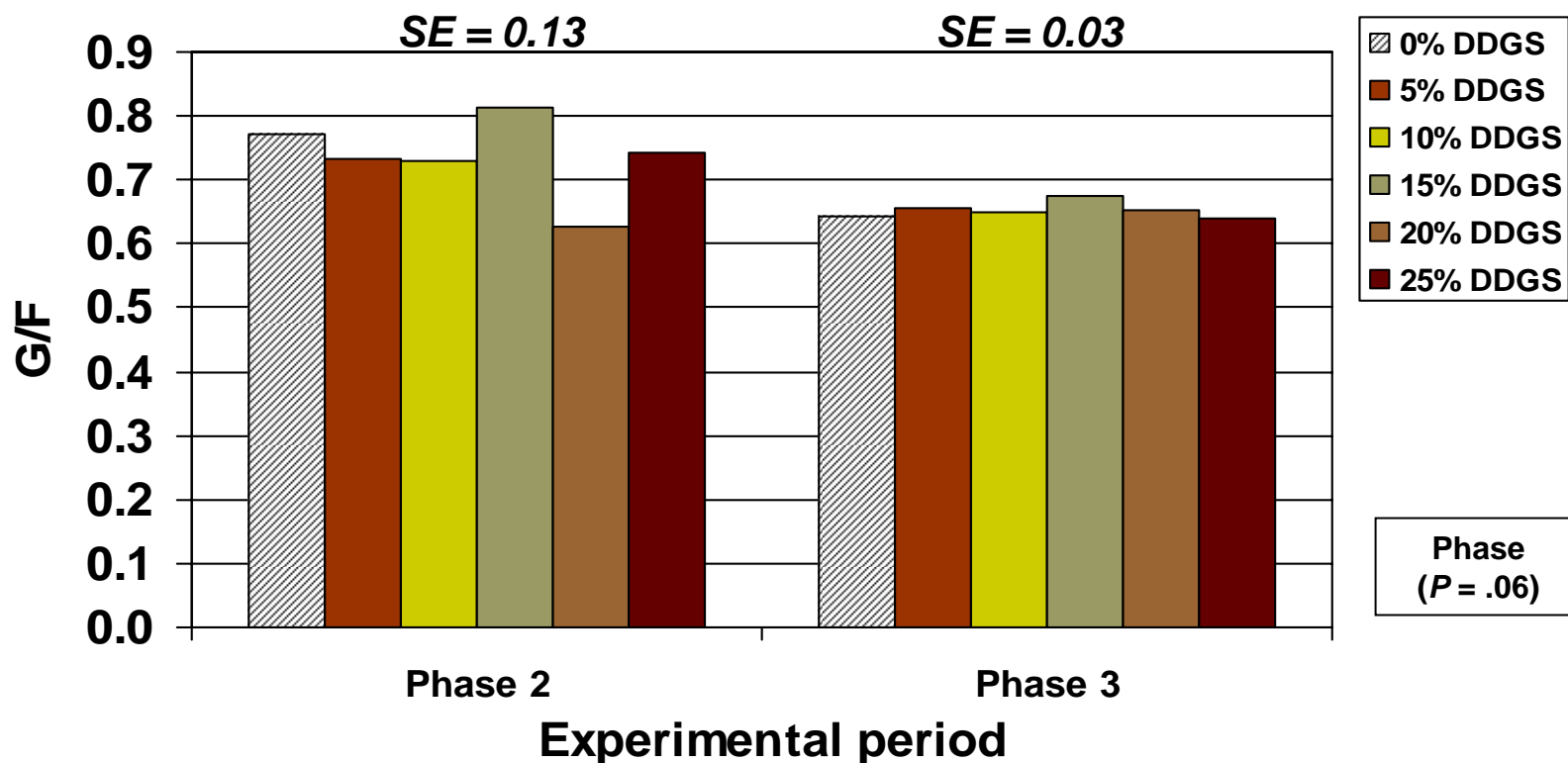


# Effect of DDGS Level on Feed Intake (Experiment 2)

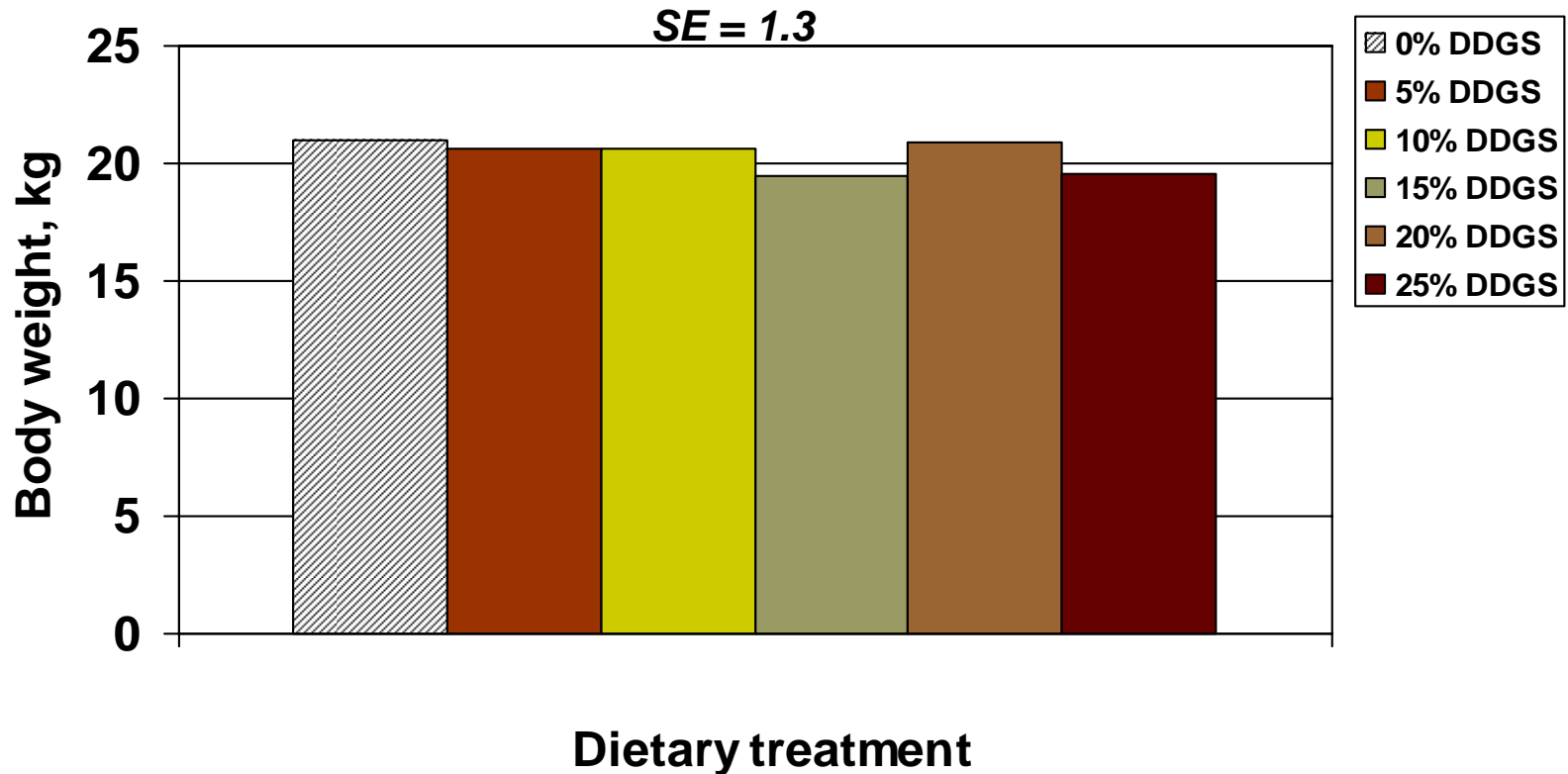


Means not sharing a common superscript letter are significantly different ( $P < .05$ )

# Effect of DDGS Level on Gain/Feed (Experiment 2)



# Effect of DDGS Level on Final BW (Experiment 2)



# Feeding Golden DDGS to Grow-Finish Pigs

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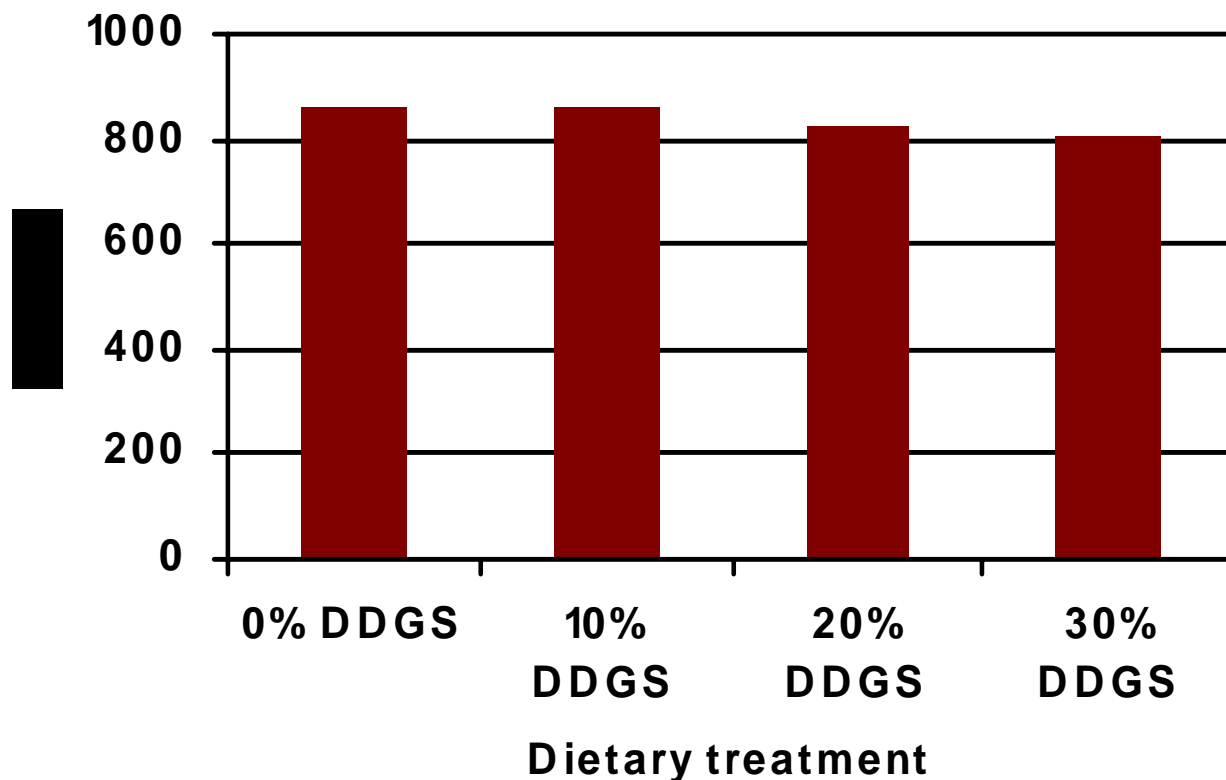


# Materials and Methods

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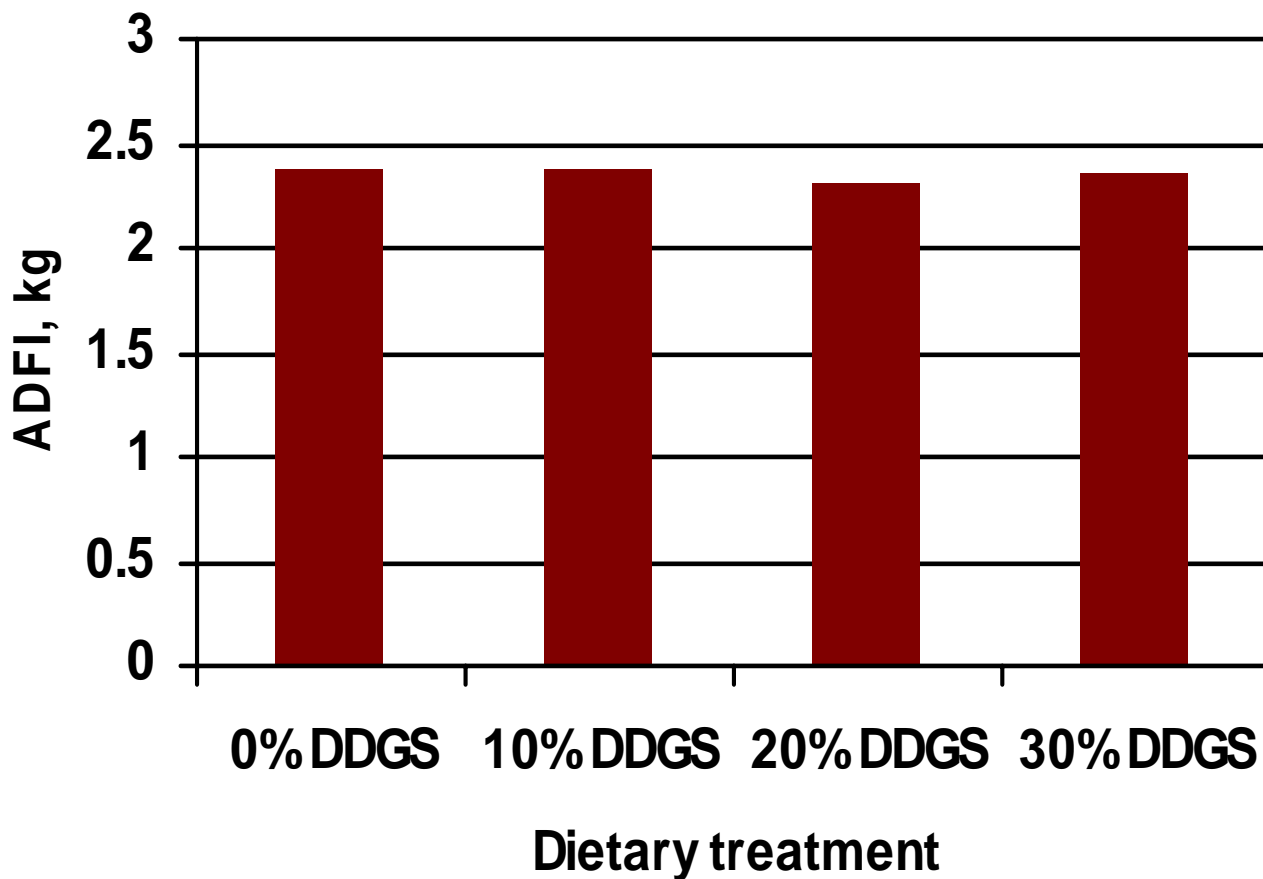
- 240 crossbred pigs (approx. 28.3 kg BW)
  - Grow-finish facilities at WCROC – Morris, MN
  - Blocked by weight, gender and litter
  - Blocks randomly assigned to 1 of 4 diet sequences
    - 5-phase feeding program
  - 0, 10, 20, or 30% DDGS diets *formulated on total lysine basis*
  - 24 pens, 10 pigs/pen, 6 replications/treatment

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



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

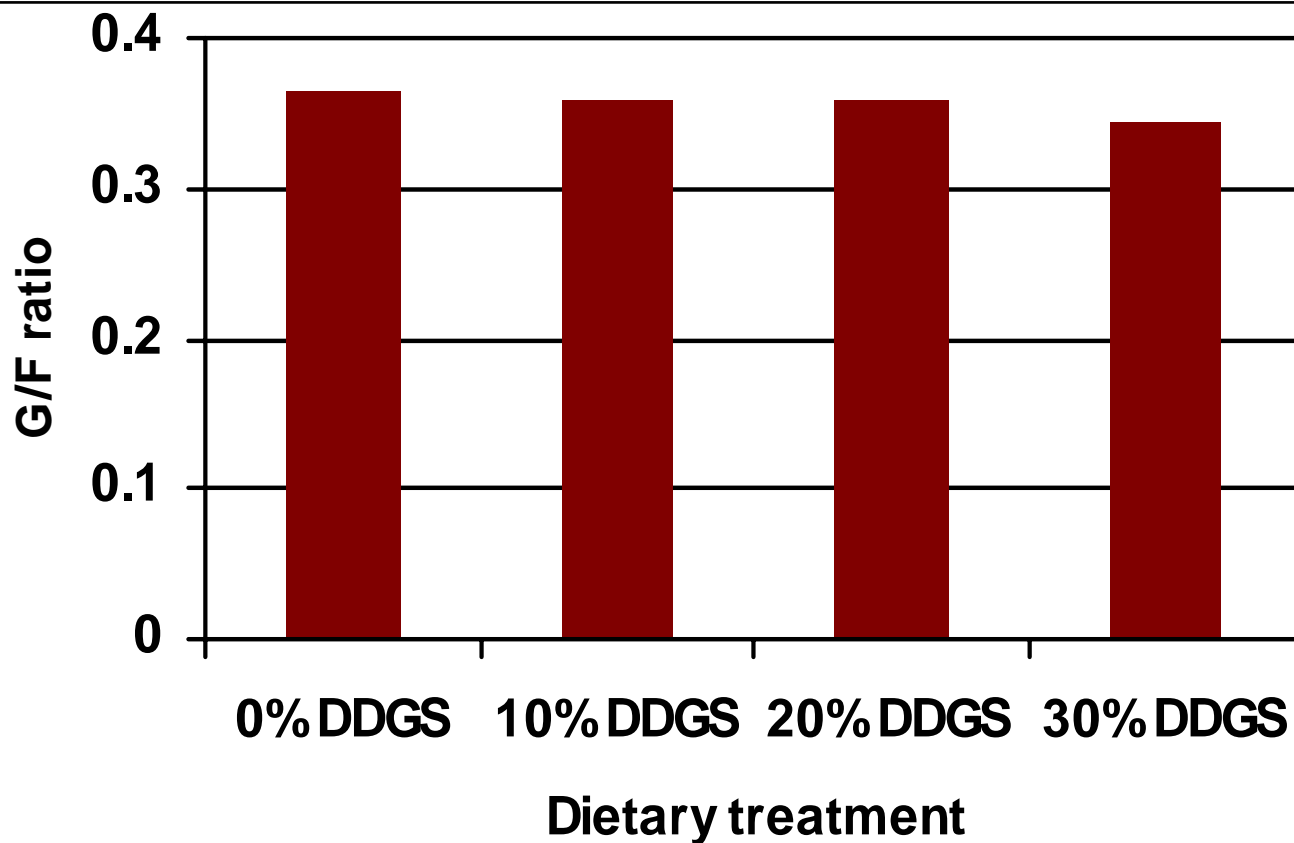
# Effect of Dietary DDGS Level on Overall ADFI of Grow-Finish Pigs



No significant differences among dietary treatments

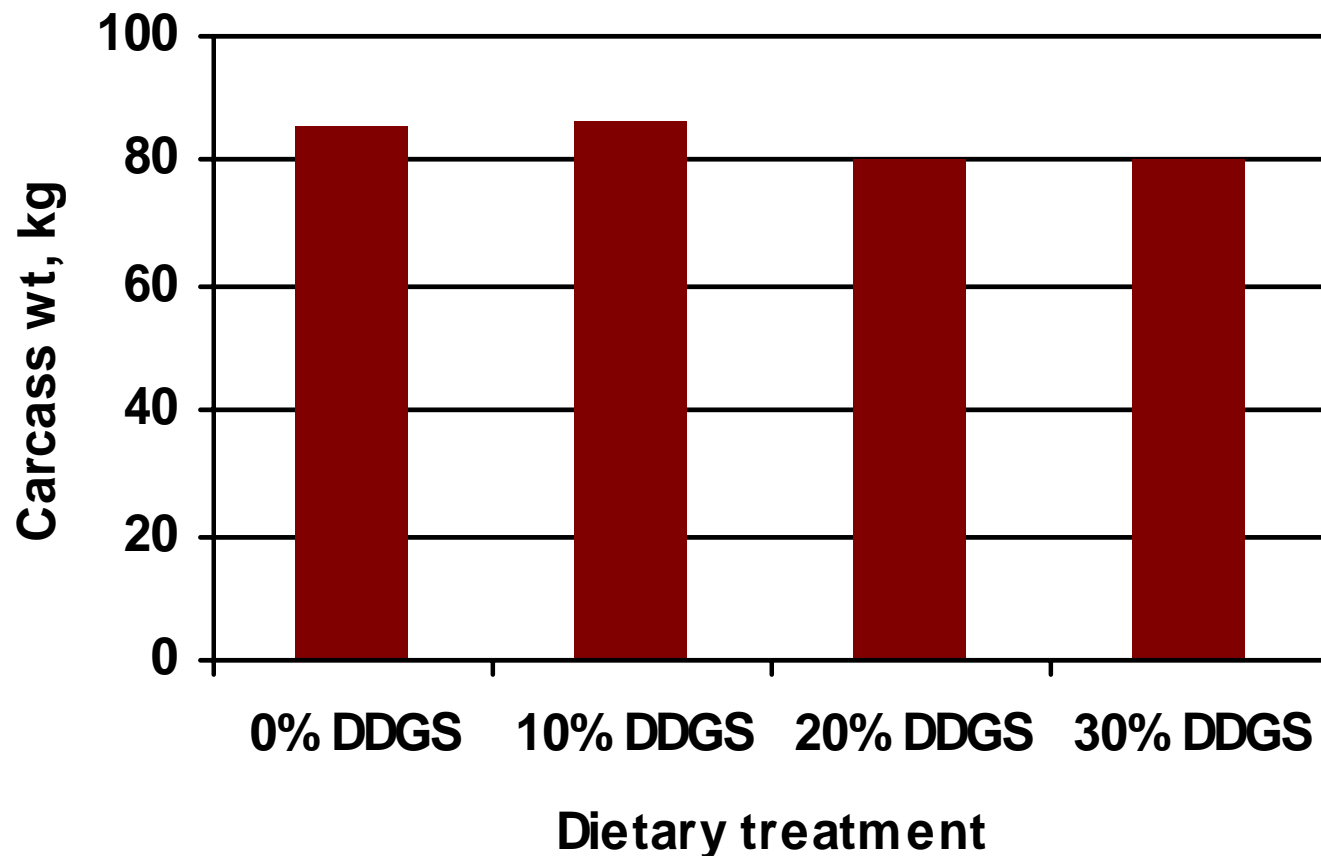


# Effect of Dietary DDGS Level on Overall G/F of Grow-Finish Pigs



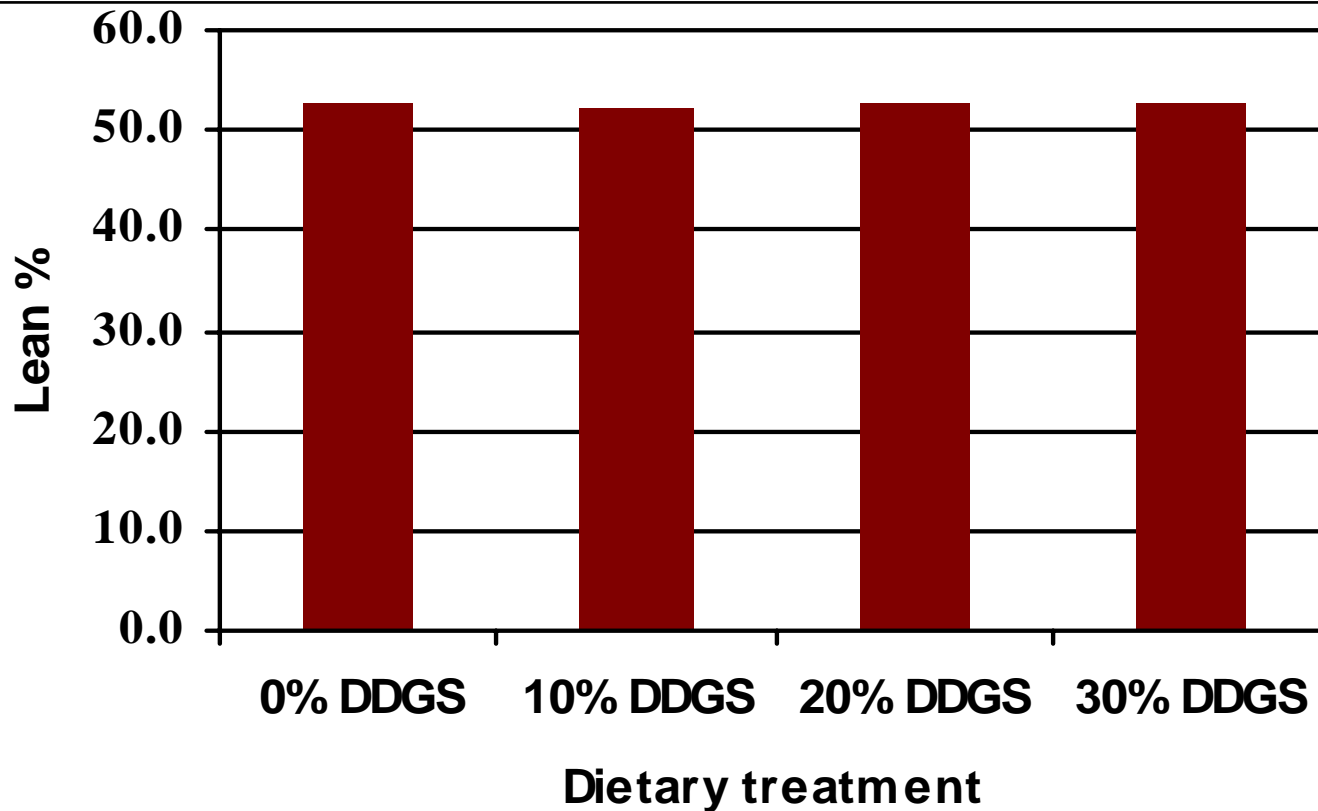
0 %, 10 % and 20% DDGS > 30% DDGS ( $P < .10$ )

# Effect of Dietary DDGS Level on Carcass Weight



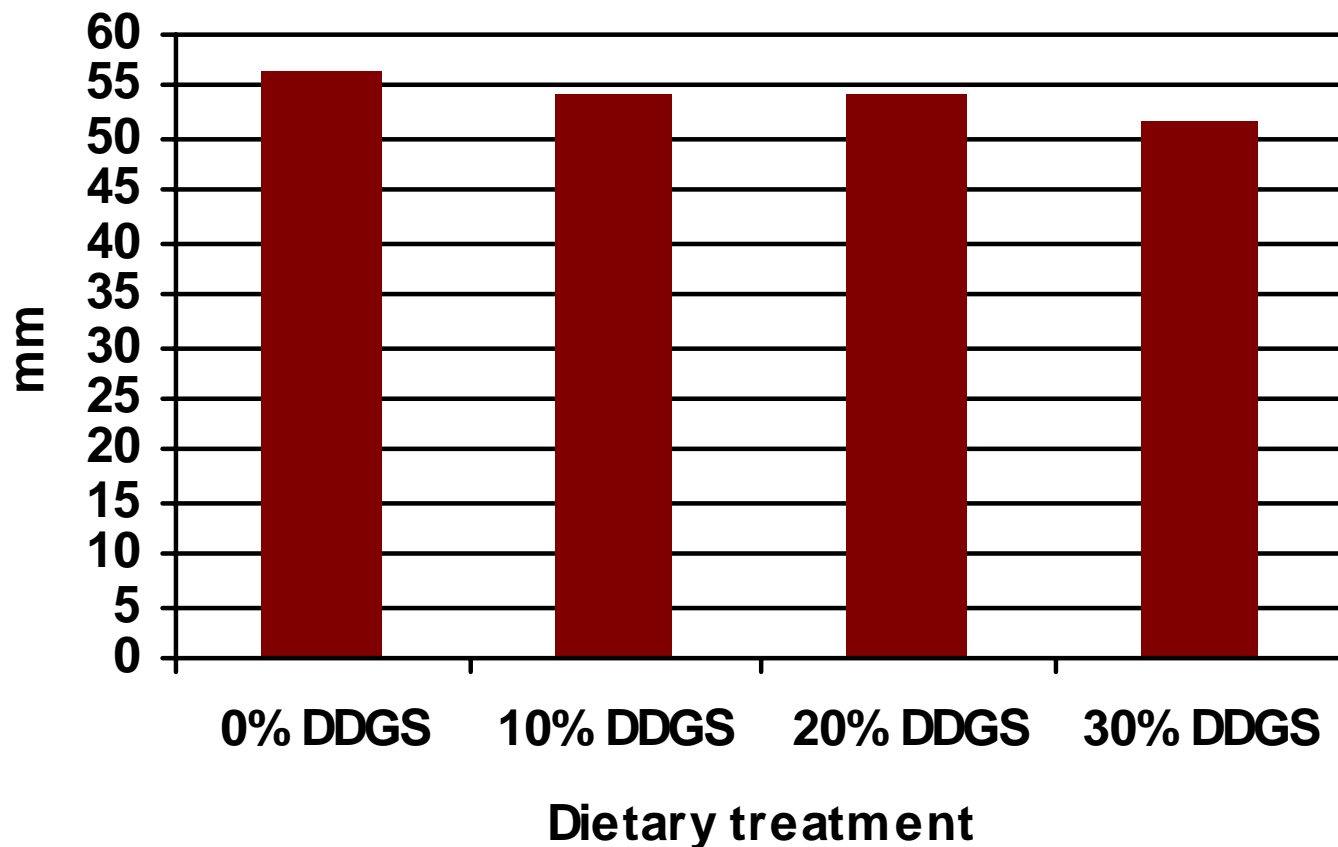
0 % and 10 % DDGS > 20% and 30% DDGS ( $P < .01$ )

# Effect of Dietary DDGS Level on % Carcass Lean



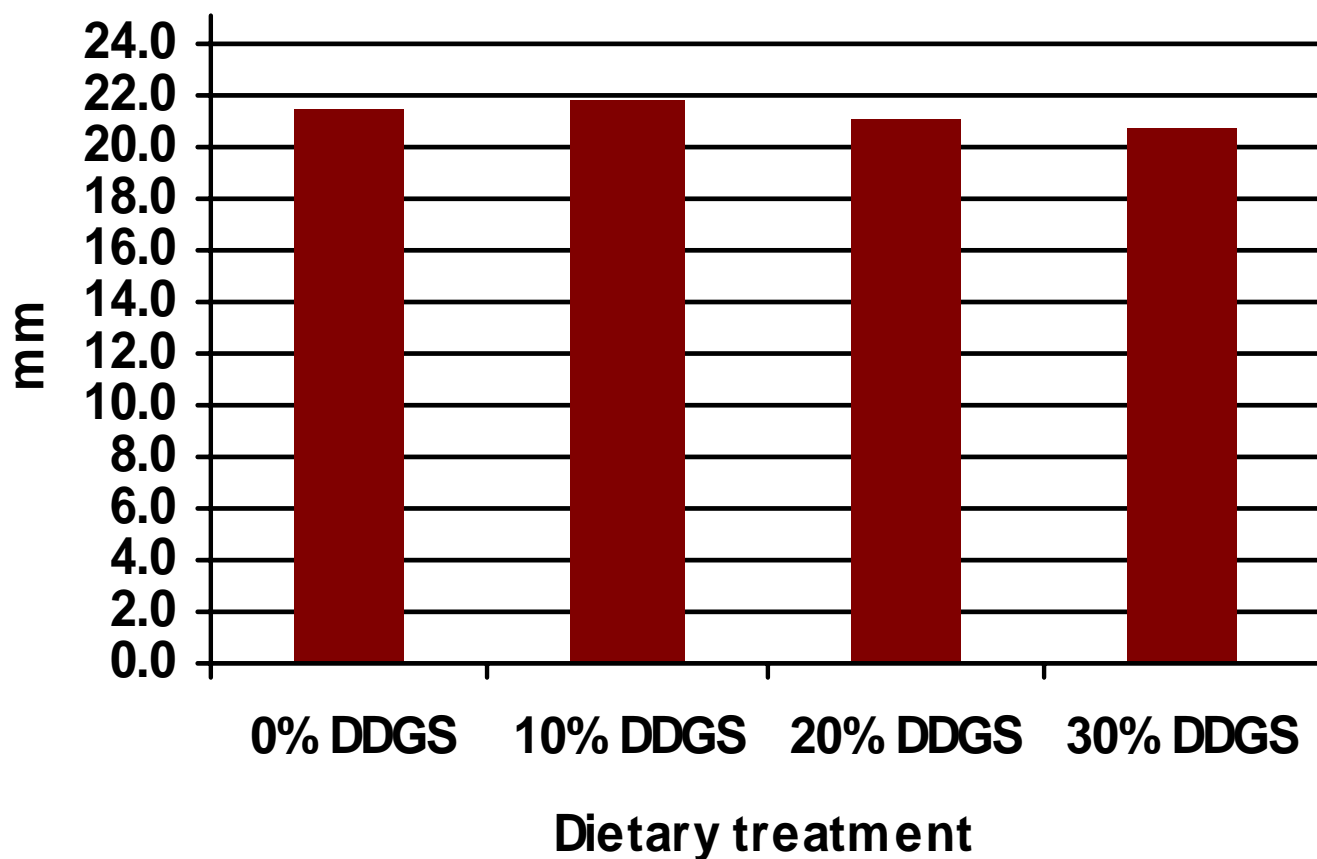
No significant differences among dietary treatments

# Effect of Dietary DDGS Level on Carcass Loin Depth



Linear decrease with increasing dietary level of DDGS ( $P < .02$ )

# Effect of Dietary DDGS Level on Carcass Backfat Depth



No significant differences among dietary treatments

# Muscle Quality Characteristics from G-F 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 <sup>b</sup>	3.2	3.2	3.1	3.1	0.8
Firmness score <sup>c</sup>	2.2	2.0	2.1	2.1	0.5
Marbling score <sup>d</sup>	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 <sup>f</sup>	2.4 <sup>fg</sup>	2.8 <sup>g</sup>	2.5 <sup>fg</sup>	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 <sup>e</sup> , %	21.4	21.5	21.8	22.1	3.1
Warner-Bratzler shear force, kg	3.4	3.4	3.3	3.3	0.5

<sup>a</sup> 0 = black, 100 = white

<sup>b</sup> 1=pale pinkish gray/white; 2=grayish pink; 3=reddish pink; 4=dark reddish pink; 5=purplish red; 6=dark purplish red

<sup>c</sup> 1 = soft, 2 = firm, 3 = very firm

<sup>d</sup> Visual scale approximates % intramuscular fat content (NPPC, 1999)

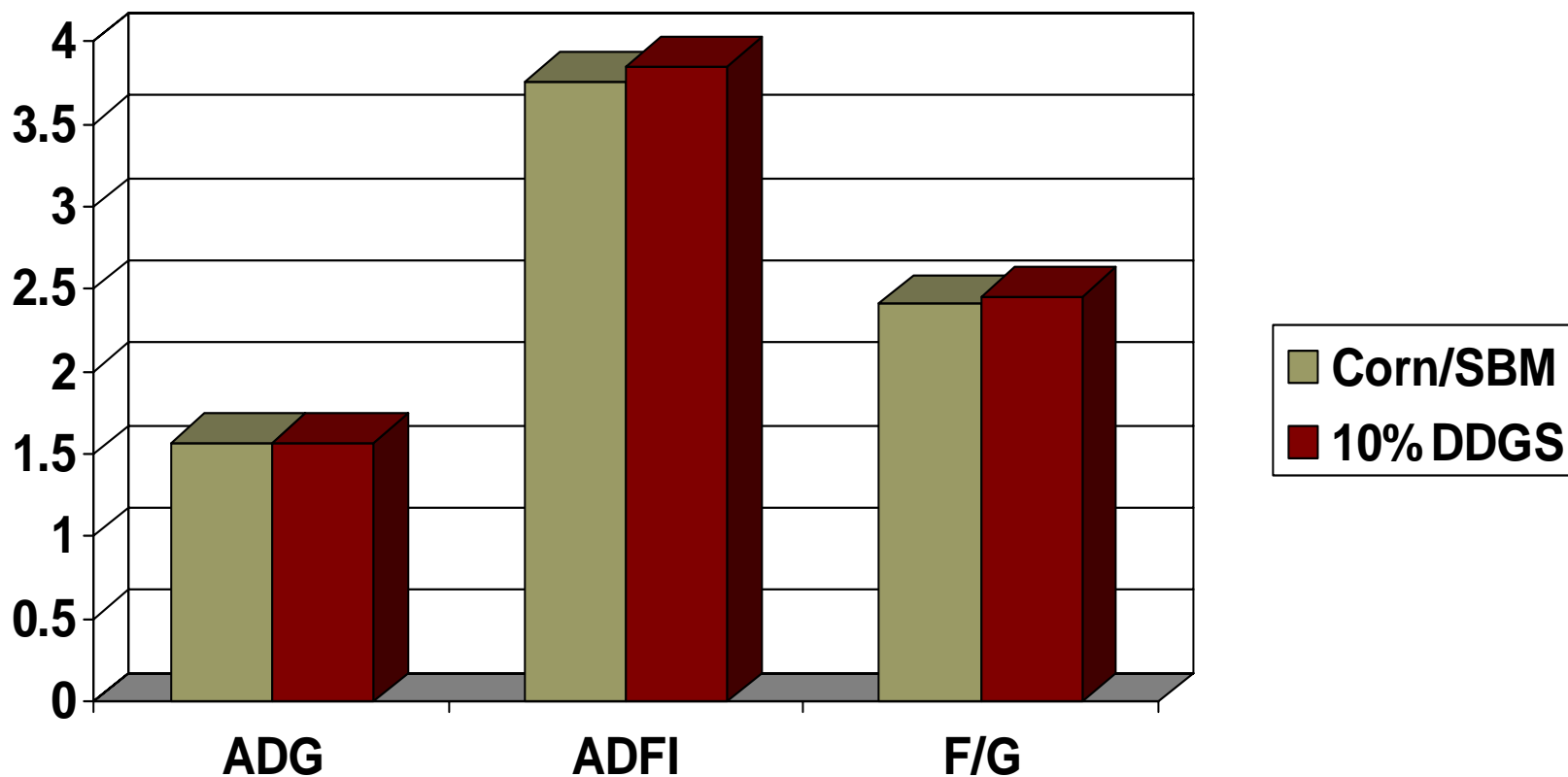
<sup>e</sup> Total moisture loss = 11-d purge loss + 24-h drip loss + cooking loss

# **Fat Quality Characteristics of Market Pigs Fed Corn-Soy Diets Containing 0 to 30% DDGS**

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

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

# Effect of Adding 10% DDGS to Grow-Finish Diets on ADG, ADFI, and F/G for a 64 d Grow-Finish Period

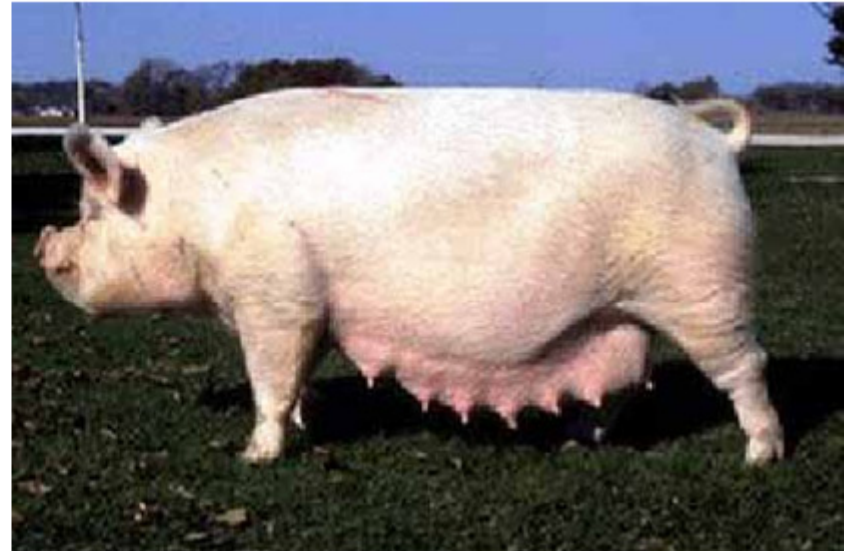


Lawrence (2003) – Hubbard Milling Commercial Feeding Trial



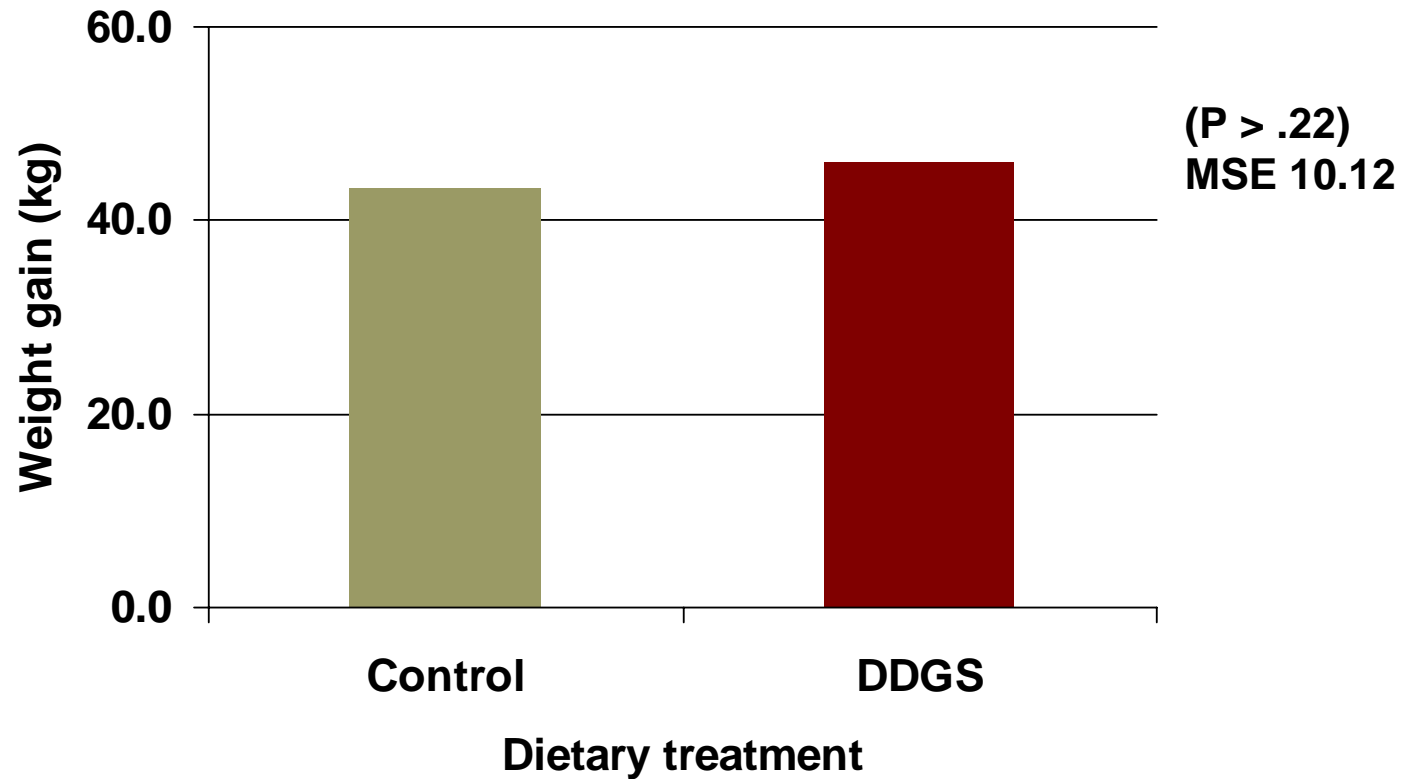
# Feeding Golden DDGS to Sows

---

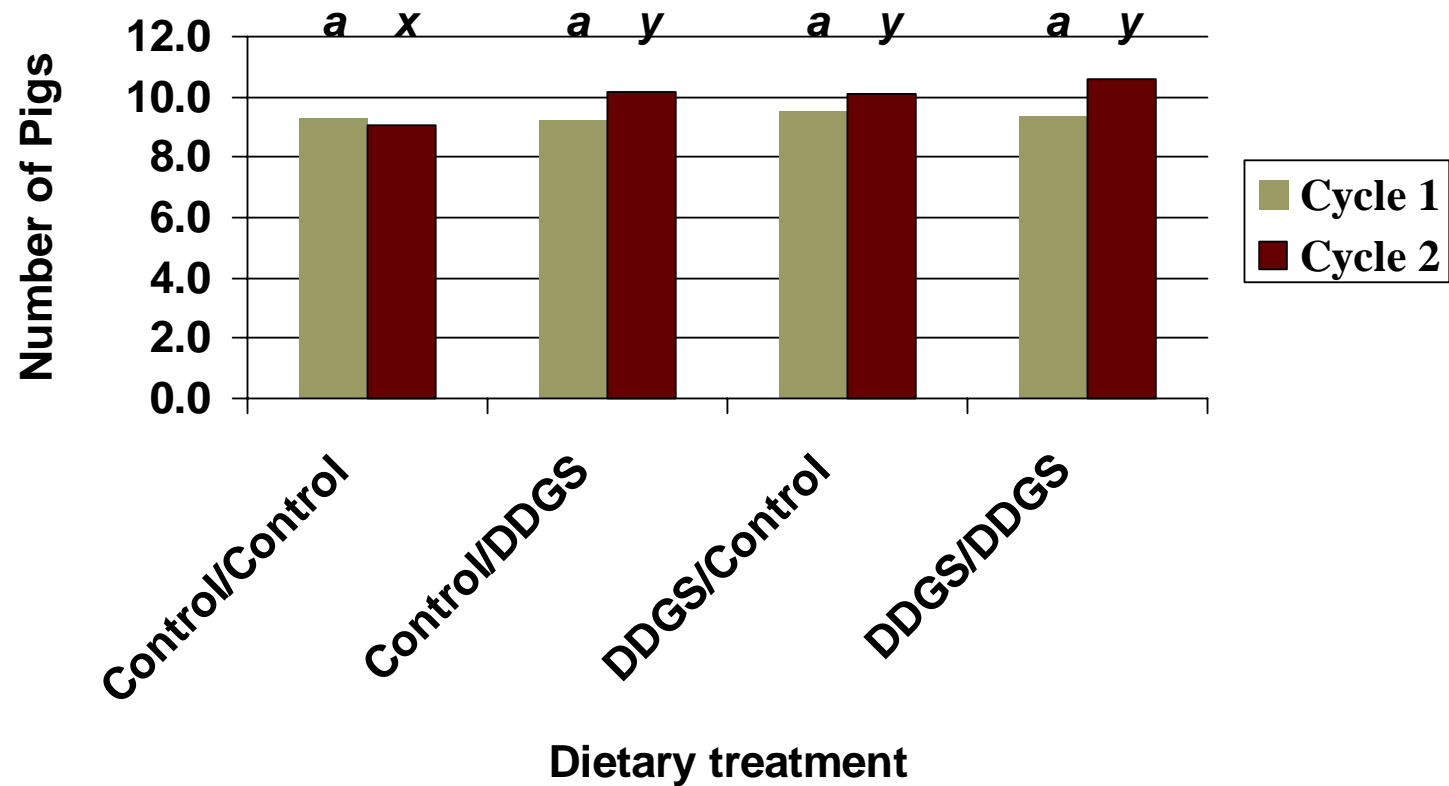


# Effect of Feeding a 50% DDGS Diet on Sow Weight Gain During Gestation (Reproductive Cycle 1)

---

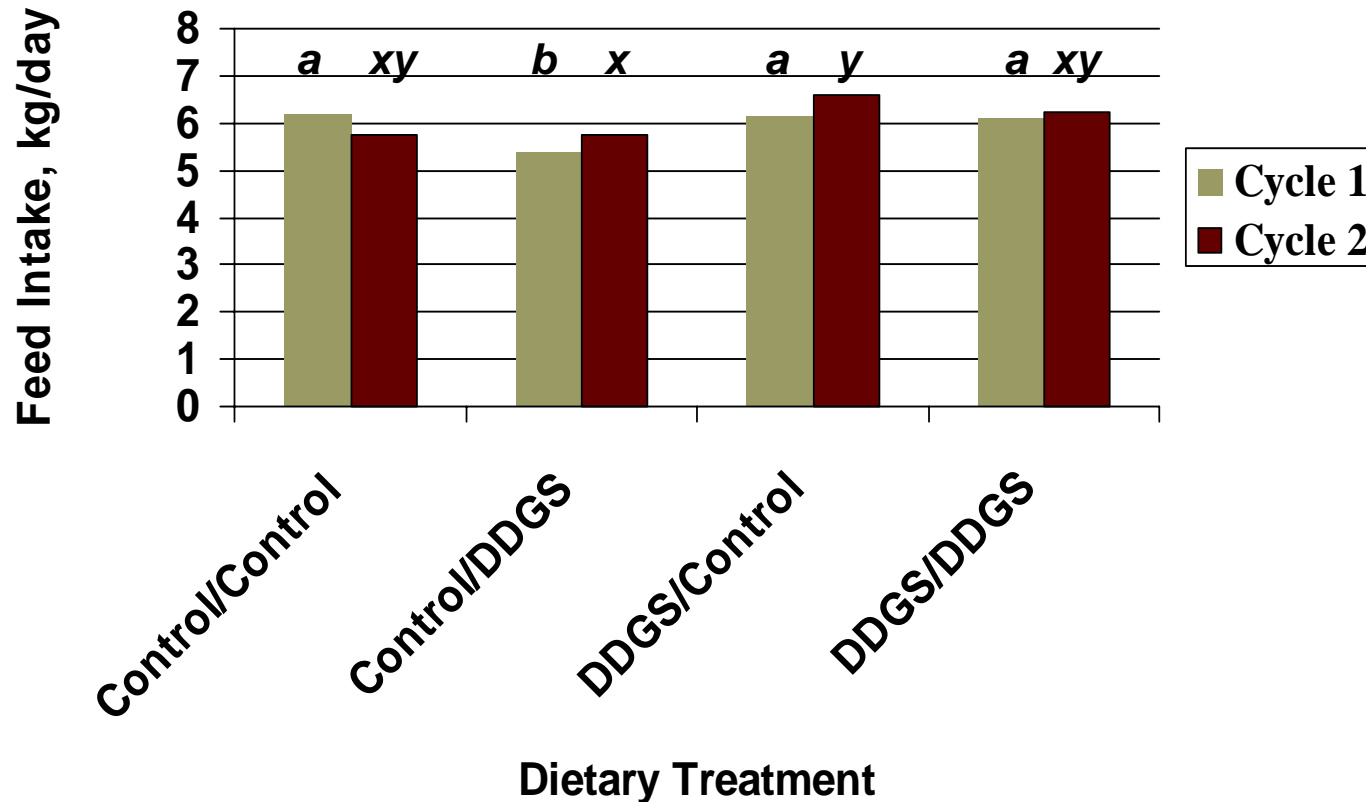


# Effect of Feeding 0 or 50% DDGS Gestation Diets and 0 or 20% DDGS Lactation Diets on Pigs Weaned/Litter



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 ( $P < .10$ ).

# DDGS and Phytase are a Key Part of Manure Phosphorus Management

---

- Adding 20% DDGS to a corn-soy diet and formulating on an available P basis
  - can reduce manure P by ~ 12%
- Adding phytase to a corn-soy diet
  - increases P bioavailability from 15% to > 45%
- Lowering dietary P, adding 20% DDGS & phytase
  - can reduce manure P excretion by 40 to 50%

# Diet Composition When 18.8% DDGS and Phytase are Added to the 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



# **Does Feeding DDGS Improve Gut Health?**

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# What is Ileitis?

---

- ❑ Porcine Proliferative Enteropathy
- ❑ Caused by *Lawsonia intracellularis*
  - Present in 96% of U.S. swine herds (Bane et al., 1997)
    - ❑ 28% of pigs affected (NAHMS, 2000)
  - Can be shed in infected pigs for up to 10 weeks
- ❑ Animals are infected by oral contact with feces from animals shedding the bacteria
- ❑ 7-10 days after infection:
  - Lesions of the intestinal wall begin to form
  - Lesions maximized around 21 days post-infection



# Clinical Forms of Ileitis

---

- Porcine Intestinal Adenomatosis (PIA)
  - Chronic form
  - Seen in growing pigs (6 - 20 weeks of age)
  - Decreased feed intake, lethargic
  
- Porcine Hemorrhagic Enteropathy (PHE)
  - Acute form, affects heavier pigs
    - Greatest frequency appears to be from 65 – 110 kg pigs
  - Massive intestinal hemorrhaging, bloody diarrhea, increase in mortality





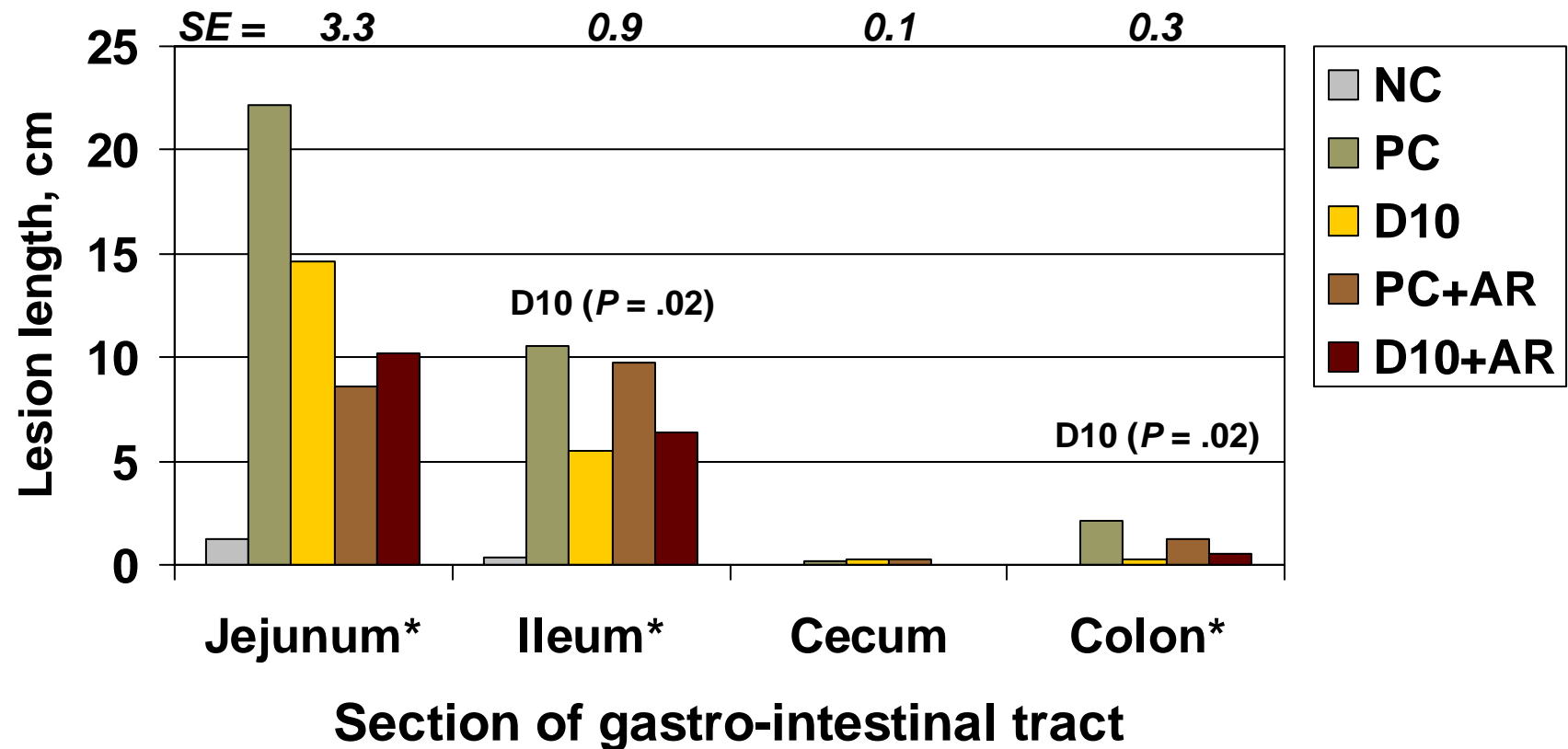
# Healthy



# Ileitis

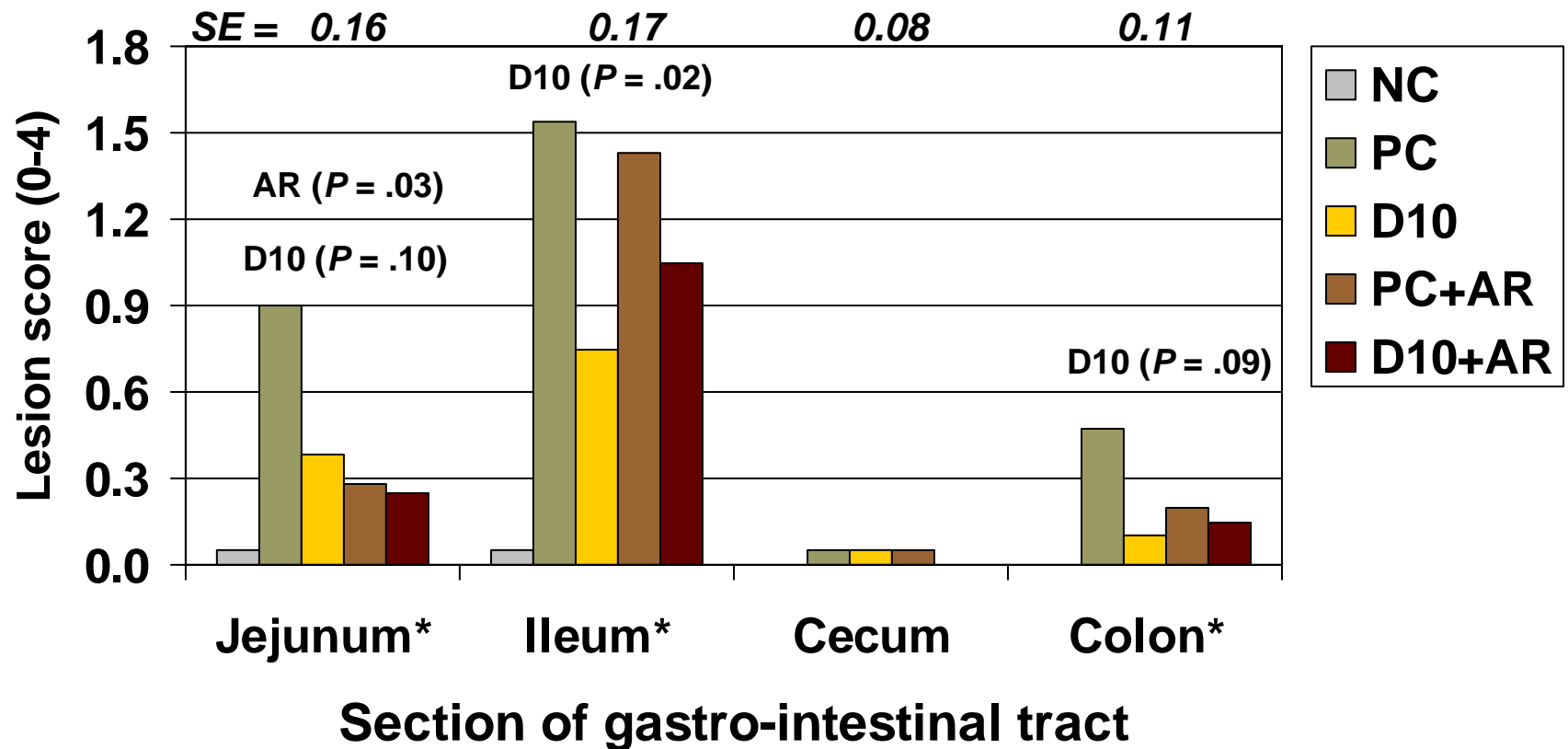


# Effect of Dietary Treatment on Lesion Length (21 d Post-Challenge) Experiment 2



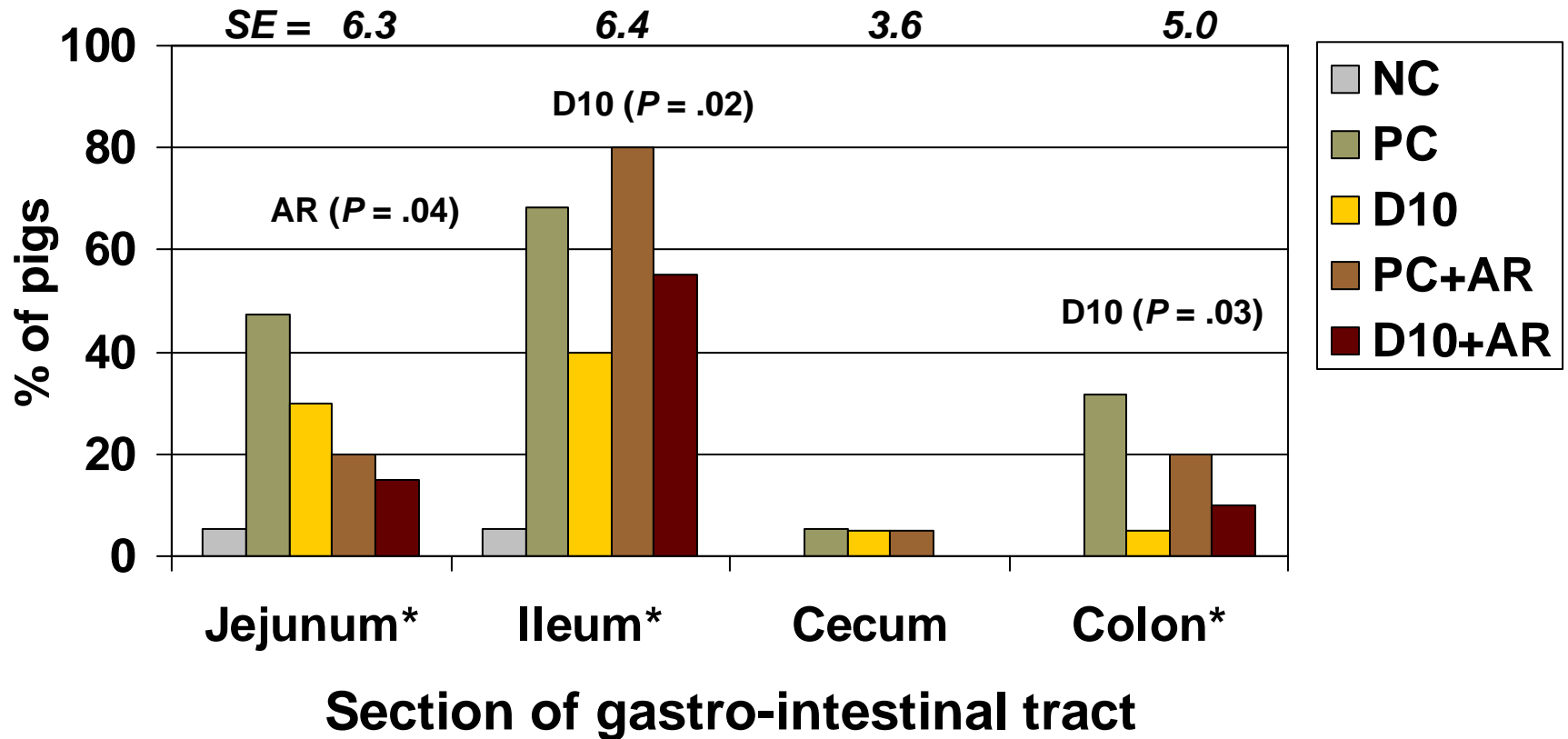
\* Effect of disease challenge ( $P < .01$ ).

# Effect of Dietary Treatment on Lesion Severity (21 d Post-Challenge) Experiment 2



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

# Effect of Dietary Treatment on Lesion Prevalence (21 d Post-Challenge) Experiment 2



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



# **Are There Components of Corn Distiller's Solubles that Are Responsible for Enteric Health Benefits?**

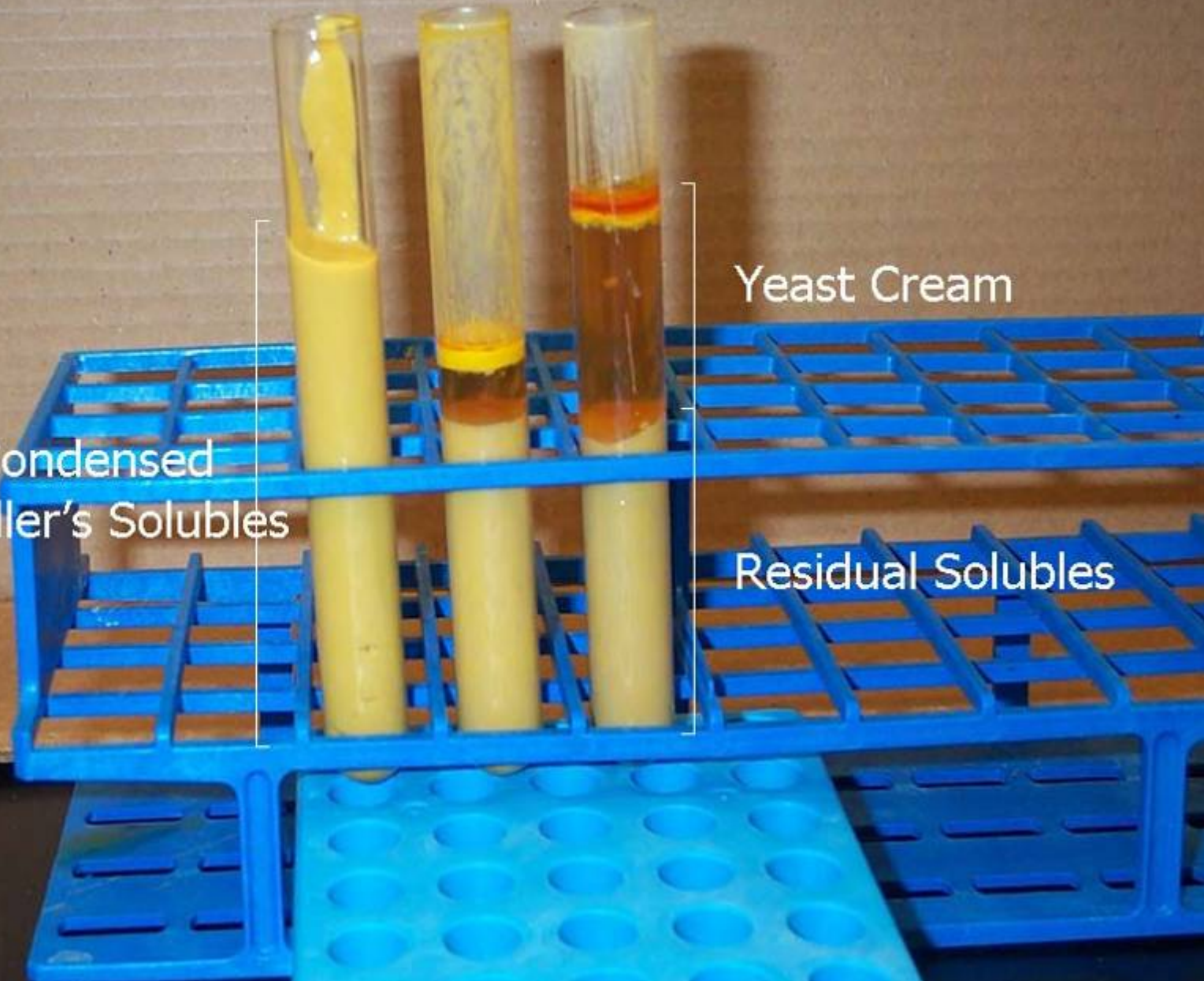
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Condensed  
Distiller's Solubles

Yeast Cream

Residual Solubles







Spray Dried Distiller's Solubles  
(DS)



Spray Dried Yeast Cream  
(YC)



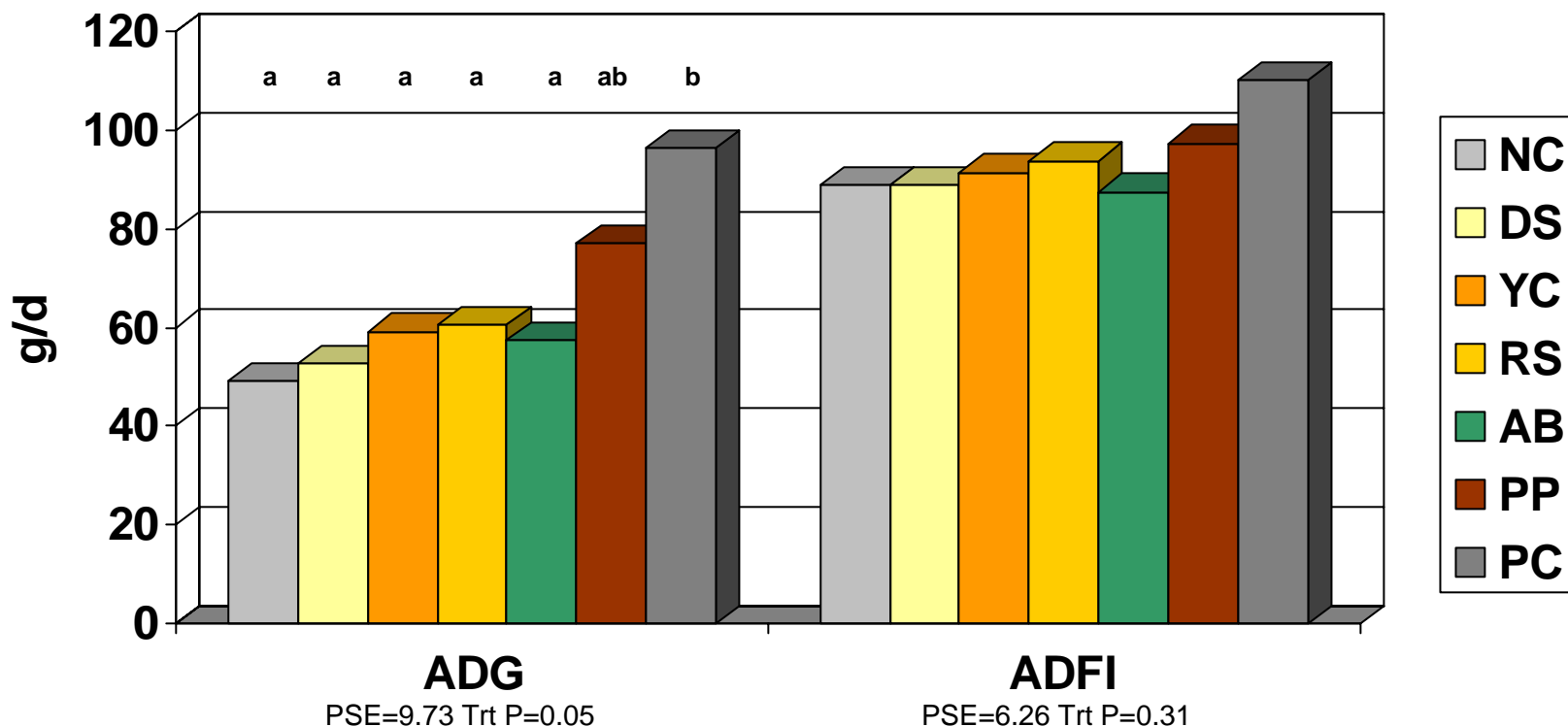
Spray Dried Residual Solubles  
(RS)

# Materials and Methods

---

- 7 dietary treatments fed from day 0 to 10 post-weaning
  - **NC = negative control**
  - **DS = spray dried distiller's solubles**
    - 15% of the diet
  - **YC = spray dried yeast cream**
    - 7.5% of the diet
    - replaced animal fat
  - **RS = spray dried residual solubles**
    - 15% of the diet
  - **AB = carbadox**
    - 50 g/ton
  - **PP = spray dried porcine plasma**
    - 6% of the diet
  - **PC = spray dried porcine plasma + carbadox**
    - 6% PP + 50 g/ton AB

# Effect of Dietary Treatment on Phase 1 ADG and ADFI (Trial 1)



NC = negative control

DS = 15% spray dried distiller's solubles

YC = 7.5% spray dried yeast cream

RS = 15% spray dried residual solubles

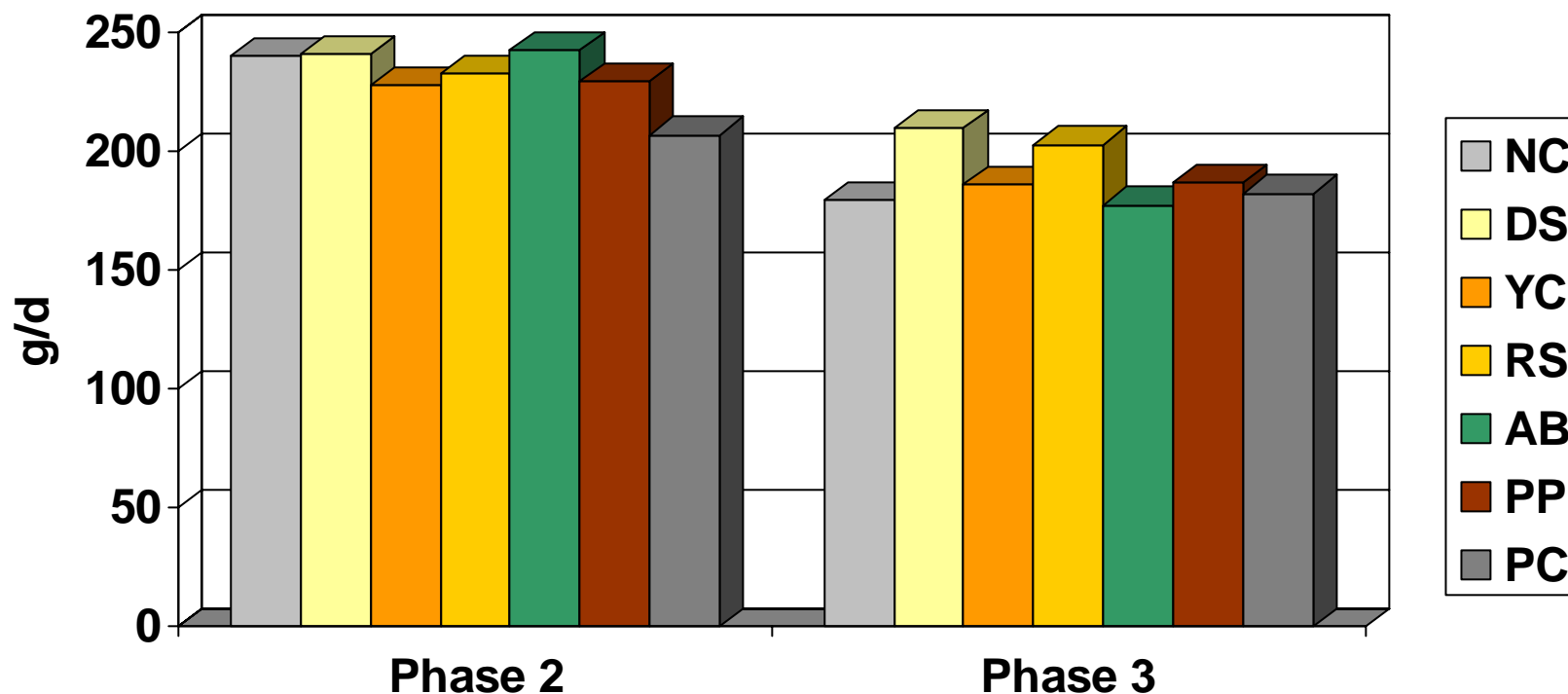
AB = 55 ppm carbadox

PP = 6% spray dried porcine plasma

PC = 55 ppm + 6% spray dried porcine plasma

a, b = Least squares means with different superscripts are different ( $P < .05$ )

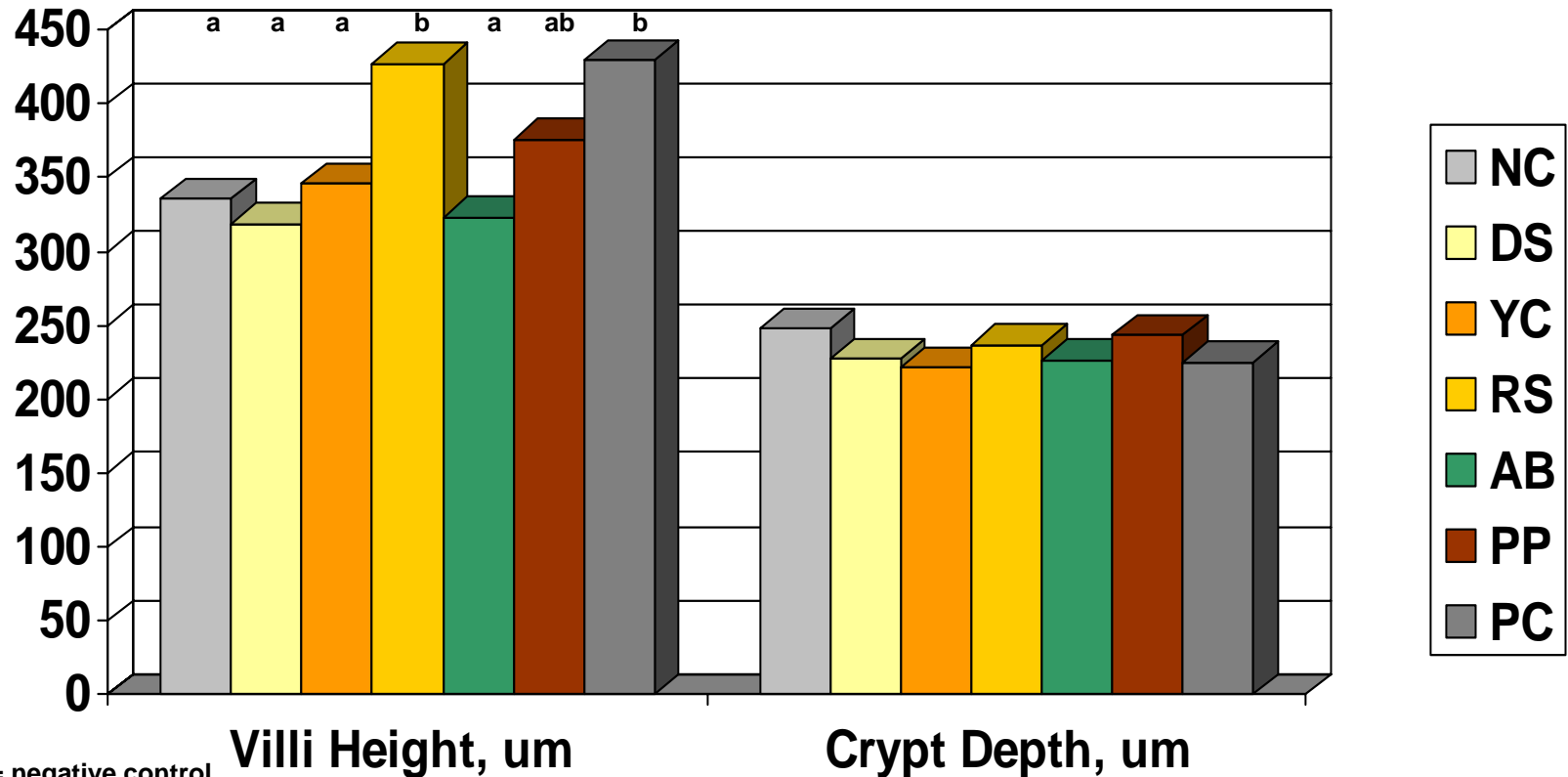
# Effect of Dietary Treatment on Relative Change in ADG (Trial 1)



NC = negative control  
DS = 15% spray dried distiller's solubles  
YC = 7.5% spray dried yeast cream  
RS = 15% spray dried residual solubles  
AB = 55 ppm carbadox  
PP = 6% spray dried porcine plasma  
PC = 55 ppm + 6% spray dried porcine plasma

Trt P-value=0.09    PSE=8.59  
Time P-value=0.77    PSE=5.25  
Time x Treatment P-value=0.91

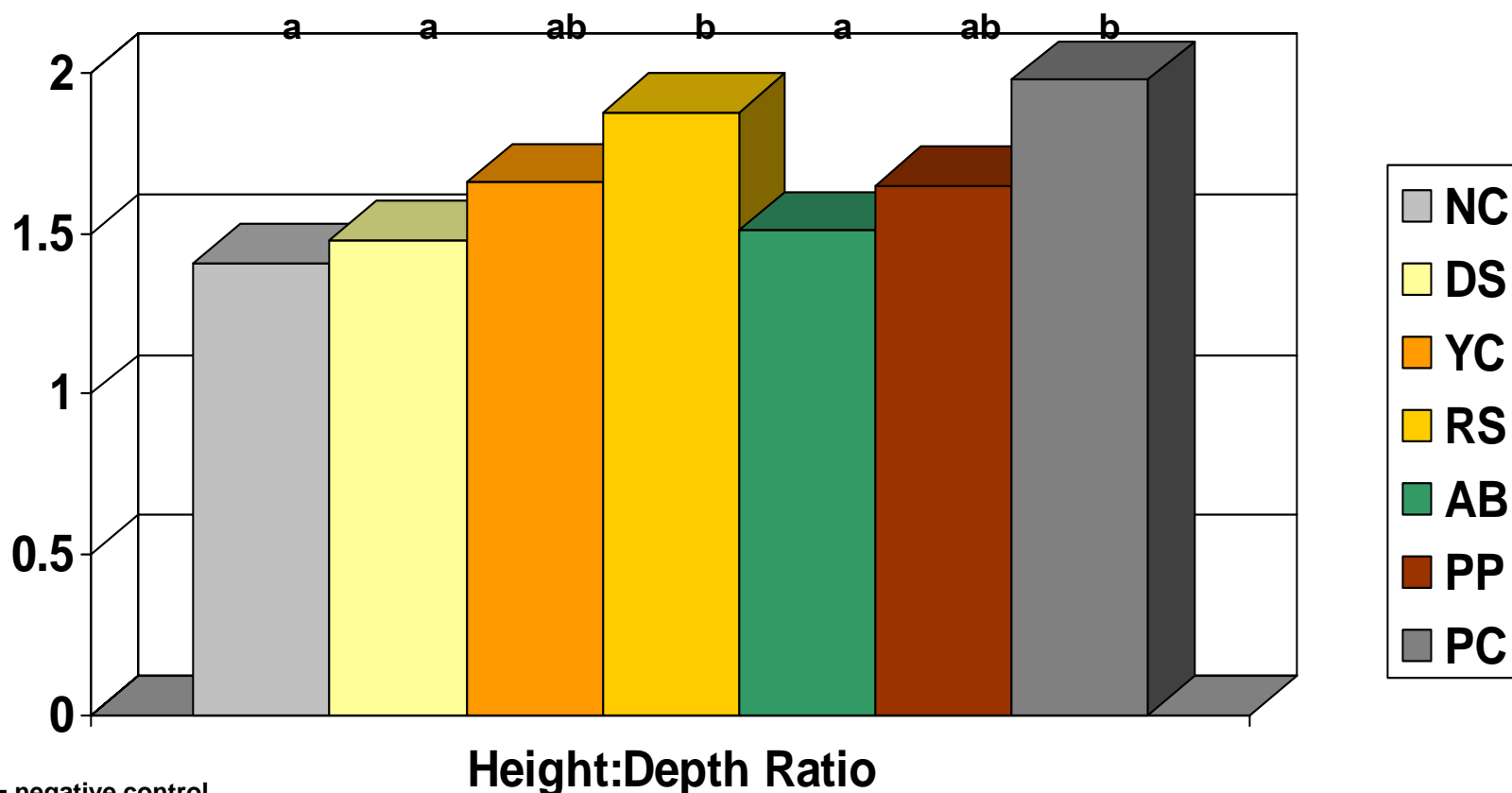
# Villi Height and Crypt Depth in the Upper 25% of the Small Intestine



NC = negative control  
DS = spray dried distiller's solubles  
YC = spray dried yeast cream  
RS = spray dried residual solubles  
AB = carbadox  
PP = spray dried porcine plasma  
PC = spray dried porcine plasma + carbadox

a, b = Least squares means with different superscripts are different ( $P < .05$ )

# Villi Height:Crypt Depth Ratio in the Upper 25% of the Small Intestine



NC = negative control

DS = spray dried distiller's solubles

YC = spray dried yeast cream

RS = spray dried residual solubles

AB = carbadox

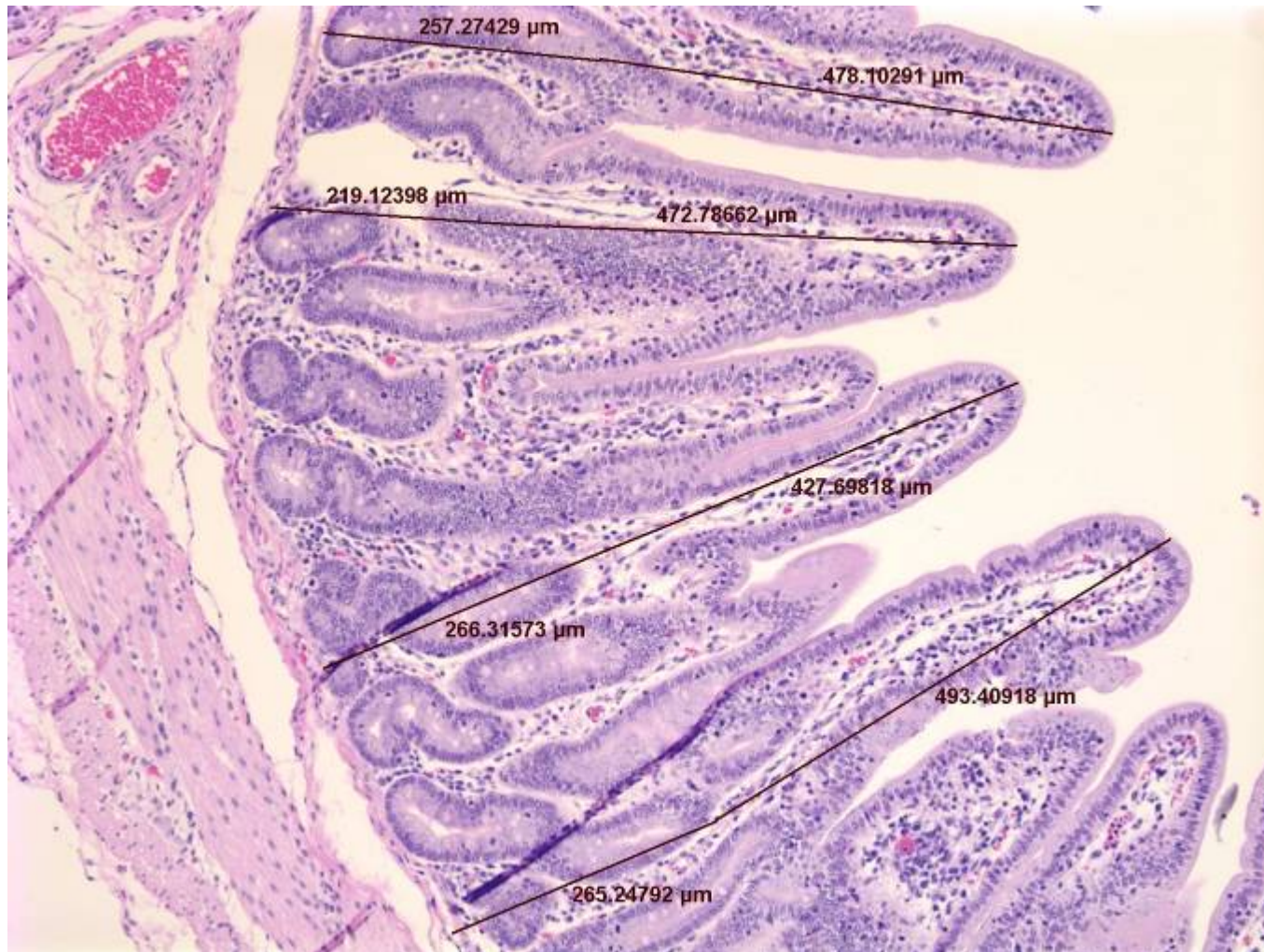
PP = spray dried porcine plasma

PC = spray dried porcine plasma + carbadox

a, b = Least squares means with different superscripts are different ( $P < .05$ )

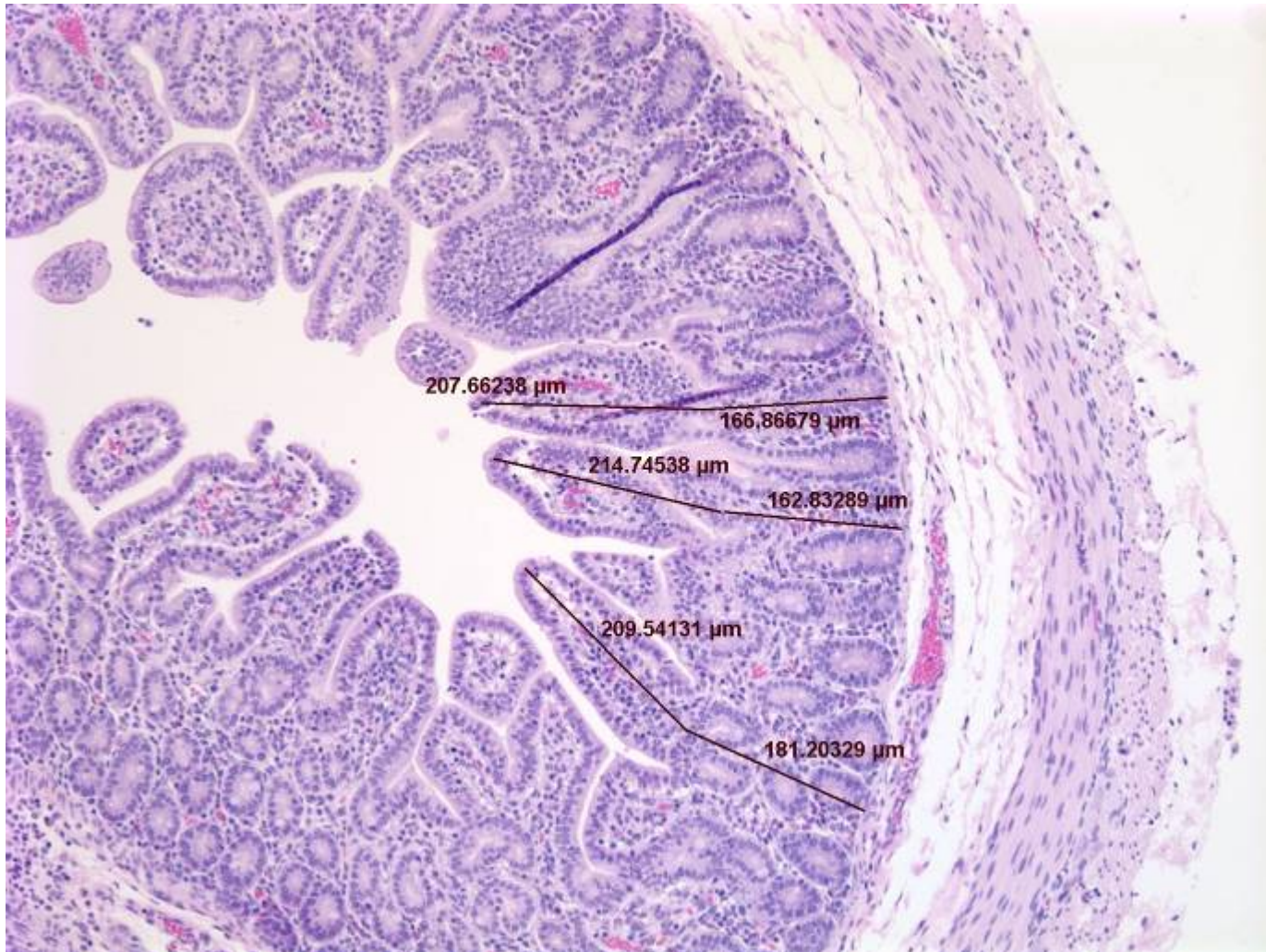


# Villi Measurements from the Upper 25% of the Small Intestine from a Pig Fed the Residual Solubles Diet (10X)



# Villi Measurements from the Upper 25% of the Small Intestine from a Pig Fed the Carbadox Diet (10X)

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# Use of Corn DDGS in Poultry Diets

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# Historical Use of DDGS in Poultry Diets

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- Fed at low inclusion rates in U.S. poultry industry for many years
  - High B vitamin content (solubles)
  - Source of unidentified growth/reproduction factors?
  - Positive effect on palatability
  - Protein source when fed at higher dietary inclusion levels

# Unidentified Growth or Hatchability Factors

---

- Growth response (Couch et al., 1957)
  - 5% DDGS in turkey diets
  - 17-32% improvement in gain
- Feed preference (Alenier & Combs, 1981)
  - 10% DDGS in chicken layer diets
- Reproduction improvement (Manley, 1978)
  - 3% DDGS in turkey breeder hen diets
  - improvement in egg numbers and hatch (late lay)



# Use of DDGS in Poultry Diets

---

- High inclusion rates have also provided good results
  - Favorable results with 25% DDGS in broiler diets
    - Waldroup et al., 1981
  - 15% DDGS in layer diets reduces fatty liver incidence
    - Jensen et al., 1974; Jensen, 1987; Akiba et al., 1983
  - 12% DDGS turkey diets gave similar performance to corn-soybean meal diets
    - Noll, 2002

# Nutritional Value of DDGS for Poultry

---

- Must use high quality DDGS
  - Golden color = high amino acid digestibility
- Excellent energy and available phosphorus source
- Nutritional value higher than previously thought
- Unidentified growth factors?
- Source of xanthophyll
- Effective partial replacement for corn, soybean meal, and dicalcium phosphate

# Recommended Inclusion Rates of DDGS for Poultry

---

- Broilers
  - 10% inclusion rates (Starter/Finisher)
    - Without energy adjustments
  - > 10%
    - With adjustments for lys, met, thr, trp, and energy
- Chicken Egg Layers
  - 10% inclusion rate
  - > 10%
    - With adjustments for lys, met, thr, trp, and energy



# Considerations in Feeding DDGS to Poultry

---

- Product quality and variability
- Metabolizable energy content
- Amino acid digestibility
- Amino acid balance
- Phosphorus availability
- Diet levels
- Source of xanthophyll
- Cost in relation to other ingredients



# DDGS As Protein Supplement

---

- Limiting amino acids (Parsons et al., 1983)
  - Lysine
  - Tryptophan
  - Arginine (perhaps equally limiting with trp)
- High inclusion rates (>10%) require dietary adjustments for:
  - Energy
  - Amino acids



# Summary of DDGS Metabolizable Energy Values for Poultry

---

- Noll 2004 Turkey TMEn (20 samples)
  - Range 2651 to 3186 kcal/kg
  - Average 2833 kcal/kg
  
- Roberson 2004
  - AMEn 2756 kcal/kg
  
- Batal and Dale 2004 Chicken TMEn
  - Range 2380 to 3079 kcal/kg
  - Average 2831 kcal/kg

# Amino Acid Content of Corn DDGS (5 Sources)

Amino acid	Range	Average	NRC, 1994
Methionine, %	0.44 – 0.56	0.49	0.60
Cystine, %	0.45 – 0.60	0.52	0.40
Lysine, %	0.64 – 0.83	0.74	0.75
Arginine, %	1.02 – 1.23	1.08	0.98
Tryptophan, %	0.19 – 0.23	0.22	0.19
Threonine, %	0.94 – 1.05	0.98	0.92

**Source: Noll and Parsons. 2003. Unpublished data.**

# True Digestible Amino Acid Levels of Corn DDGS for Poultry (5 Sources)

---

<b>Amino acid</b>	<b>True Dig. Amino Acid, %</b>	<b>Average</b>	<b>Digestibility Coefficient, %</b>	<b>Average</b>
Methionine	0.35 – 0.53	0.43	86 - 90	88
Cystine	0.28 – 0.57	0.40	66 - 85	76
Lysine	0.37 – 0.74	0.53	59 - 83	71
Arginine	0.73 – 1.18	0.93	80 - 90	86
Tryptophan	0.14 – 0.21	0.18	76 - 87	82
Threonine	0.61 – 0.92	0.74	67 - 81	75

**Source: Noll and Parsons. 2003. Unpublished data.**

# Availability of Phosphorus in DDGS

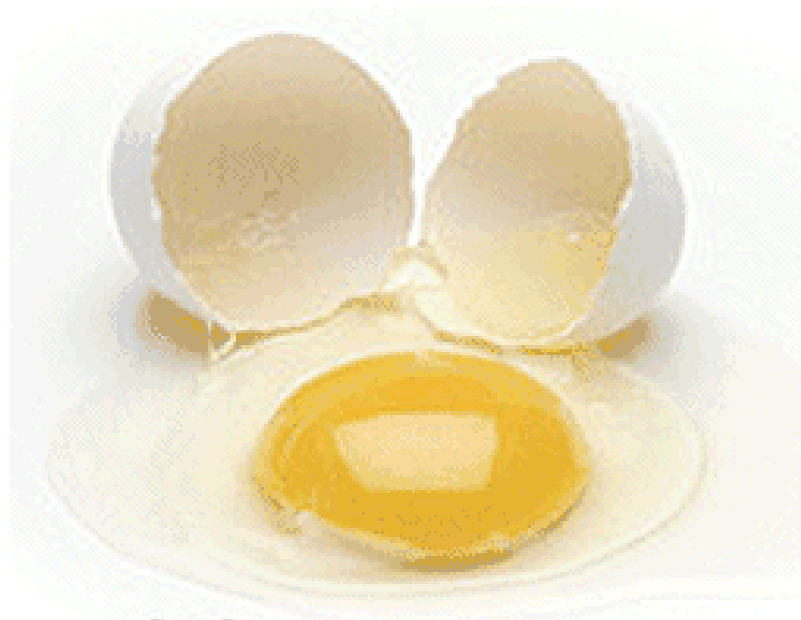
Ingredient	P, %	P, avail. %	% P Avail.
Corn*	.28	.08	28
SBM*	.62	.22	35
DDGS*	.72	.39	54
DDGS (U of GA)	.74	~.47	61-68 (64)
DDGS (U of IL)	.73	~.6	69-102 (82)
DDGS (MSU)			76-85 (80)

\*Poultry NRC (1994)

# Xanthophyll Content of Corn and Corn By-Products

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- Corn 15-25 mg/kg
- Corn Gluten Meal 130-200 mg/kg
- DDGS 15-40 mg/kg
  - SBM replacement in diet



# DDGS in Chicken Layer Diets

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# Results from Recent Layer Trials Feeding “New Generation” DDGS (University of Georgia)

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- Hy-line W35 laying hens (21 to 43 weeks of age) fed diets containing:
  - 0% DDGS – 2800 kcal ME/kg
  - 15% DDGS – 2800 kcal ME/kg
  - 0% DDGS – 2870 kcal ME/kg
  - 15% DDGS – 2870 kcal ME/kg
- No differences in egg production except when low energy, 15% DDGS diet was fed (reduction)
- No differences in egg weight, specific gravity, Haugh units, yolk color, or shell breaking strength

**Source: Lumpkins, Batal, and Dale. 2003.**

# Effect of Dietary DDGS and Energy Level in Layer Diets on % Egg Production (22-42 wks)

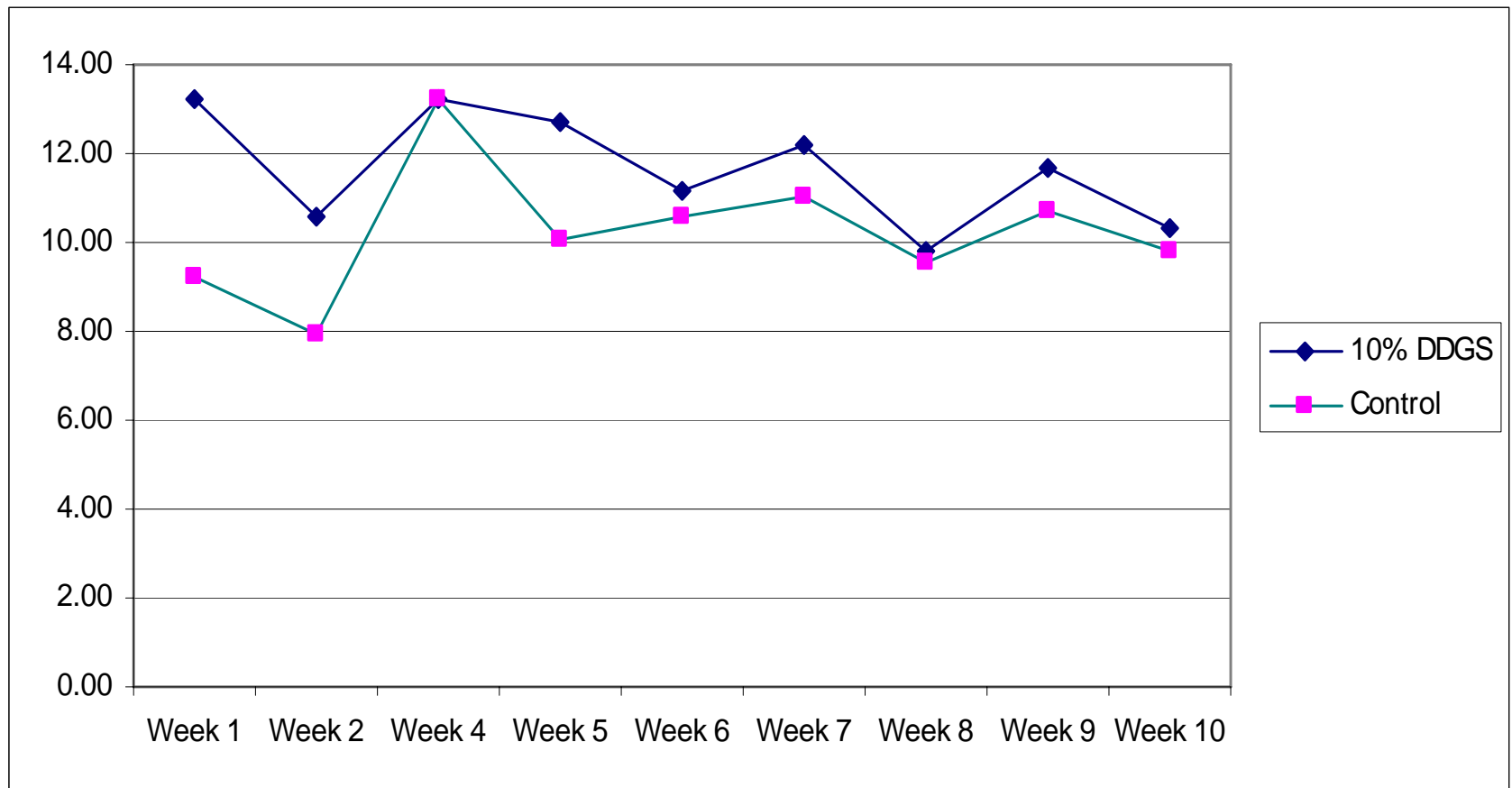
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Energy Density	DDGS Level (%)	
	0	15
High (2870 Kcal/kg)	90.2	89.7
Low (2800 Kcal/kg)	89.2	87.6

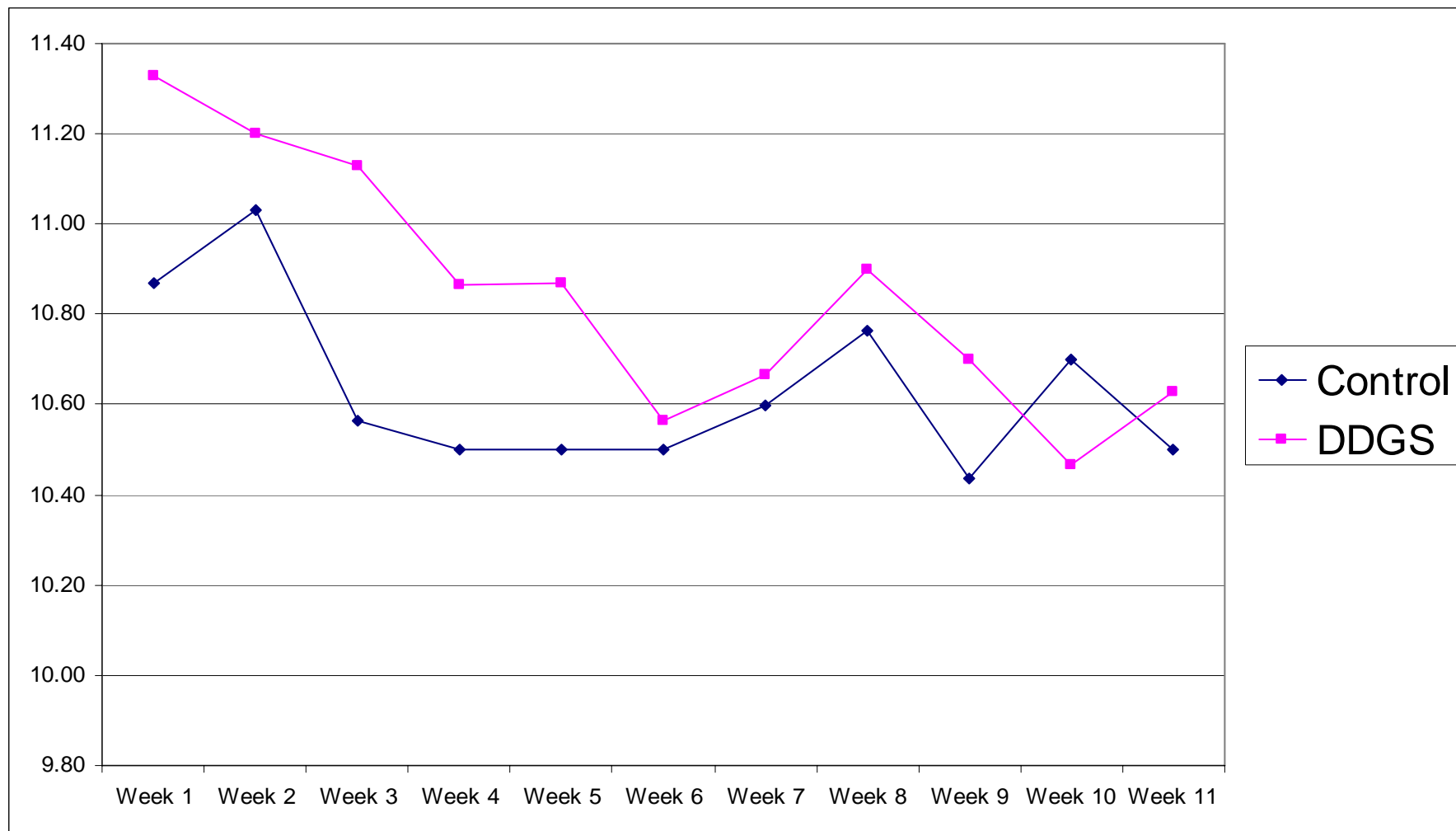
Source: Lumpkins et al., 2003



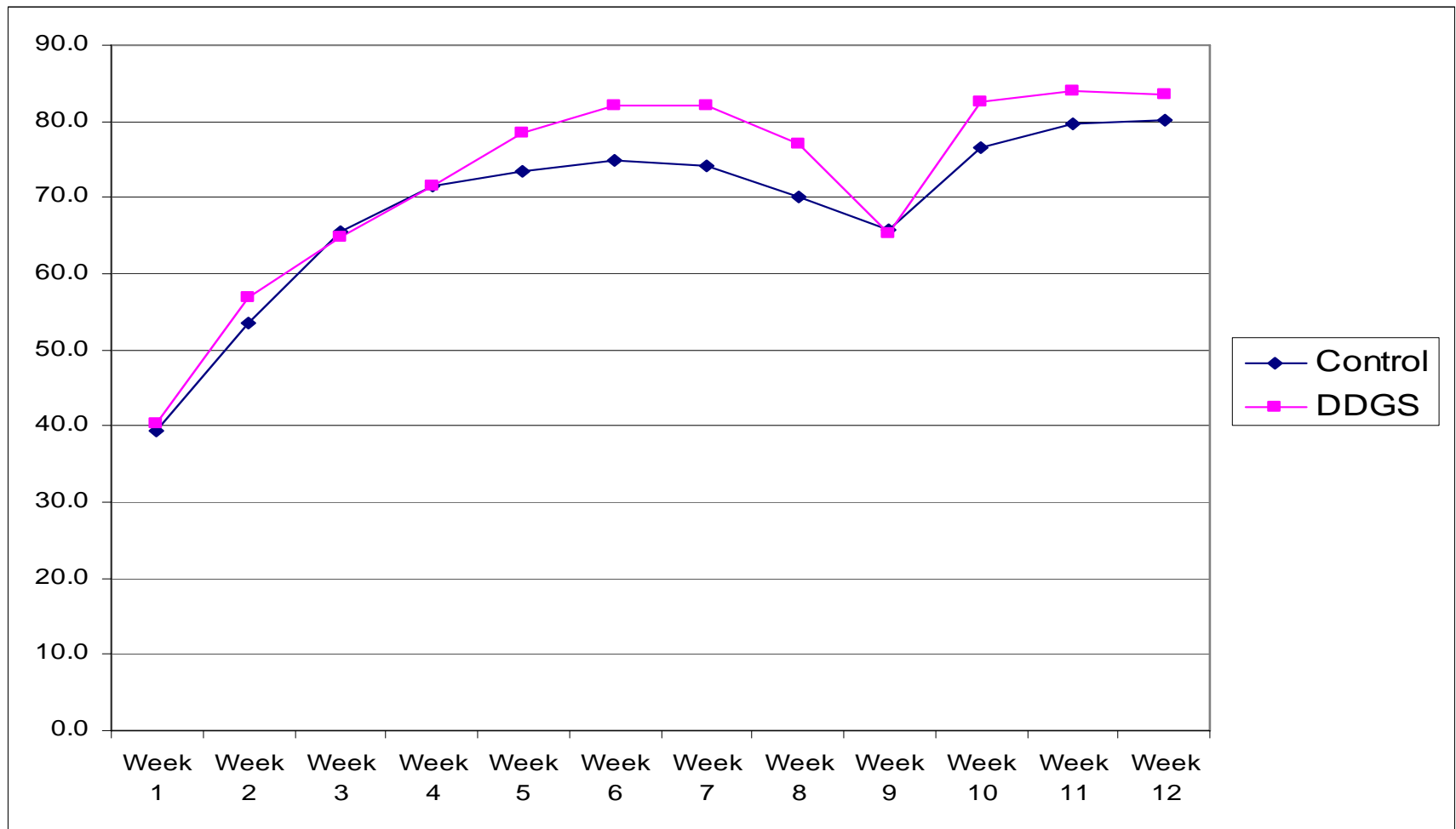
# Dietary Xanthophyll Content During a 12-Wk Layer Trial - Jalisco Mexico



# Differences in Egg Yolk Color (Roche Units) in Eggs Produced by Layers Fed Control and DDGS Diets – Jalisco Mexico



# Average Percentage of Production by Week for Layers Fed Control and DDGS Diets – Jalisco Mexico



## **Egg Production and Quality When Laying Hens Were Fed Diets Containing 10% DDGS (Jalisco, Mexico)**

---

Performance	Control	DDGS	P value
% Egg Production	68.7	72.4	.02
% First Class Eggs	66.2	68.9	.10
Egg Wt./Hen/Wk, kg	.31	.32	.11
% Dirty Eggs	1.4	2.2	.002
Egg Yolk Color	10.6	10.8	.02



# Effect of Dietary DDGS Level on Layer Performance and Yolk Color

---

- Roberson, 2004
  - Hy-line W36
  - Two 9/10 wk trials
  - Diets contained 0, 5, 10, 15% DDGS

# Results (Roberson, 2004)

- ❑ Inconsistent response of DDGS level on:
  - Weekly egg production (1 wk of 9 wks)
  - Egg specific gravity
    - ❑ Exp 1 ( 1 wk of 4)
    - ❑ Exp 2 – no effect
- ❑ No effect of DDGS level on egg weight
- ❑ Yolk color was darker when DDGS was fed in Exp 1 and 2



# Effect of Dietary DDGS Level on Egg Yolk Color (Roberson Experiment 2)

<b>DDGS Level</b>	<b>L*</b>	<b>a*</b>	<b>b*</b>	<b>Roche</b>
0 %	77.9 <sup>a</sup>	2.70 <sup>d</sup>	88.1	8.63 <sup>b</sup>
5 %	75.9 <sup>b</sup>	4.19 <sup>c</sup>	86.7	8.98 <sup>a</sup>
10 %	76.2 <sup>b</sup>	4.74 <sup>b</sup>	87.5	9.02 <sup>a</sup>
15 %	75.9 <sup>b</sup>	6.11 <sup>a</sup>	87.7	9.22 <sup>a</sup>
SE	0.4	0.19	0.6	0.08
Trt, p<	0.004	<0.001	0.352	0.001
Linear, p<	0.007	<0.001	0.846	<0.001



# Summary – Roberson, 2004

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- ❑ Corn DDGS can be fed as high as 15% in layer diets using 1250 kcal/lb ME for DDGS without affecting egg production or egg shell quality.
- ❑ Egg yolk color darkened quickly with 10+% DDGS and within 2 months with 5% DDGS compared to feeding a corn-SBM diet.



# Results from Recent Broiler DDGS Trials

---

- Broiler chicks (0 to 18 days) fed diets containing:
  - 0% DDGS - 3000 kcal ME/kg
  - 15% DDGS – 3000 kcal ME/kg
  - 0% DDGS – 3200 kcal ME/kg
  - 15% DDGS – 3200 kcal ME/kg
- ADG and G/F higher for 3200 kcal ME diets
- No difference in performance between 0% or 15% DDGS within dietary energy level

**Source: Lumpkins, Batal, and Dale. 2003.**

# Results from Recent Broiler DDGS Trials

---

- ❑ Broiler chicks (0 to 42 days) fed isocaloric and isonitrogenous diets containing:
  - 0% DDGS
  - 6% DDGS
  - 12% DDGS
  - 18% DDGS
- ❑ No difference in ADG and G/F when 0, 6, or 12% DDGS diets were fed
- ❑ ADG was reduced for chicks fed 18% DDGS
- ❑ No difference in carcass yields

**Source: Lumpkins, Batal, and Dale. 2003.**

## Effect of Feeding Increasing Levels of DDGS to Broilers on Body Weight and F/G (6-Wk Trial)

---

<b>Dietary Level of DDGS</b>	<b>Body Wt. 42d, Kg</b>	<b>Feed/Gain</b>
0	1.47	1.57
6	1.47	1.56
12	1.45	1.57
18	1.43	1.59

# DDGS Broiler Trial – CP Taiwan

---



# Tongshan Farm



# Growth Performance of Broilers Fed 0 or 10% DDGS (day 15-39) at CP-Taiwan

Measurement	Control	10% DDGS
Initial Number of Birds	450	450
Final Number of Birds	441	439
% Livability	98.0	97.6
Day 15 Body Wt., g/bird	392	395
Day 28 Body Wt., g/bird	1246	1232
Day 39 Body Wt., g/bird	1988	1981
Day 15-28 ADFI, g/bird	986	978
Day 28-39 ADFI, g/bird	1860	1865
Day 15-39 ADFI, g/bird	2846	2843
Feed/Gain, Day 15-39	1.78	1.79



# DDGS in Market Turkey Diets

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# Current Market Turkey Research

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- Roberson, 2003
  - Hen turkeys – grow/finish diets
  - Isocaloric; digestible amino acids
- Noll ongoing – 4 experiments
  - Tom turkeys – grow/finish diets (5-19 wks)
  - Formulation - isocaloric; digestible amino acids



# DDGS and Turkey Hen Diets

DDGS %	BW 105 d, kg	F/G 75-105 d
Exp. 1*		
0	8.53	2.99
9	8.41	3.07
18	8.23	3.21
27	8.16	3.21
Exp. 2		
0	8.51	3.44
7	8.46	3.54
10	8.50	3.46

\* Significant Linear Effect

Roberson, 2003

# Market Tom Trials-Grow/Finish Diets (University of Minnesota)

---

Trial*	Trt	DDGS,%	BW, kg	F/G
1	Control	0	18.9	2.44
	DDGS	12-8	19.0	2.48
2	Control	0	19.2	2.64
	DDGS	11-8	19.2	2.65
3	Control	0	18.4	2.67
	DDGS	10	18.3	2.63

\*Trial weeks of age: 1 = 5-19 wks, 2 = 8-19 wks, 3 = 11-19 wks

# Recommendations for Use of DDGS in Poultry Diets

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- ❑ Corn DDGS can be fed up to 15% of the diets to chicken layers and broilers and up to 10% of the diet to turkeys
- ❑ Formulate with minimums for tryptophan and arginine, especially as diet protein is decreased
- ❑ Formulate on basis of digestible amino acid content
- ❑ Use AMEn value of 2750 to 2850 kcal/kg
- ❑ Increase available phosphorus value for DDGS to 65% (higher than NRC '94)



# **U of M DDGS Web Site**

## **[www.ddgs.umn.edu](http://www.ddgs.umn.edu)**

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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

