# Benefits and Limitations of Feeding DDGS to Grower-Finisher Pigs

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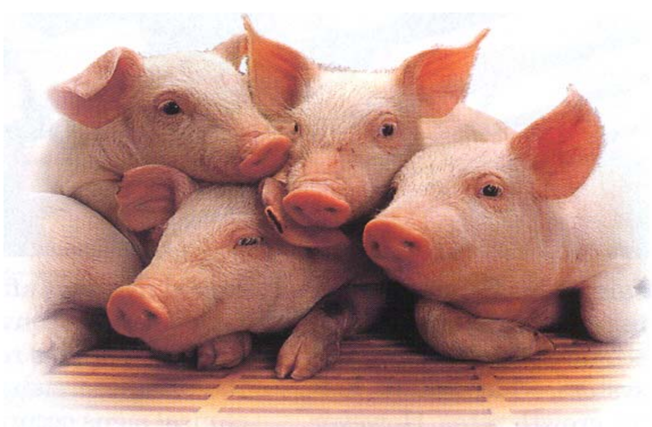
# Overview

- 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 on:
  - growth performance
  - carcass composition
  - pork fat and lean quality
  - gut health
  - manure management



- Opportunities for using liquid distiller's by-products

# U.S. DDGS Production

- Currently ~ 165 ethanol plants in the U.S.
  - 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 < 2 weeks

- 2007 – 14.6 million metric tonnes
  - 64% dried vs. 36% wet (cattle feed)
  - 11% fed to swine

# Maximum Inclusion Rates of DDGS in Swine Diets

**(Based Upon University Trials)**

- Nursery pigs (> 7 kg)
  - 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 phosphorus basis

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

- Grower-finisher diets ~ 80-85%
  - 10 - 40% of 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 are 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

# 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 |
|---|---|---|---|---|
| Gross energy, kcal/kg | 3,891 | 3,848 | 4,776 | 4,334 |
| 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)

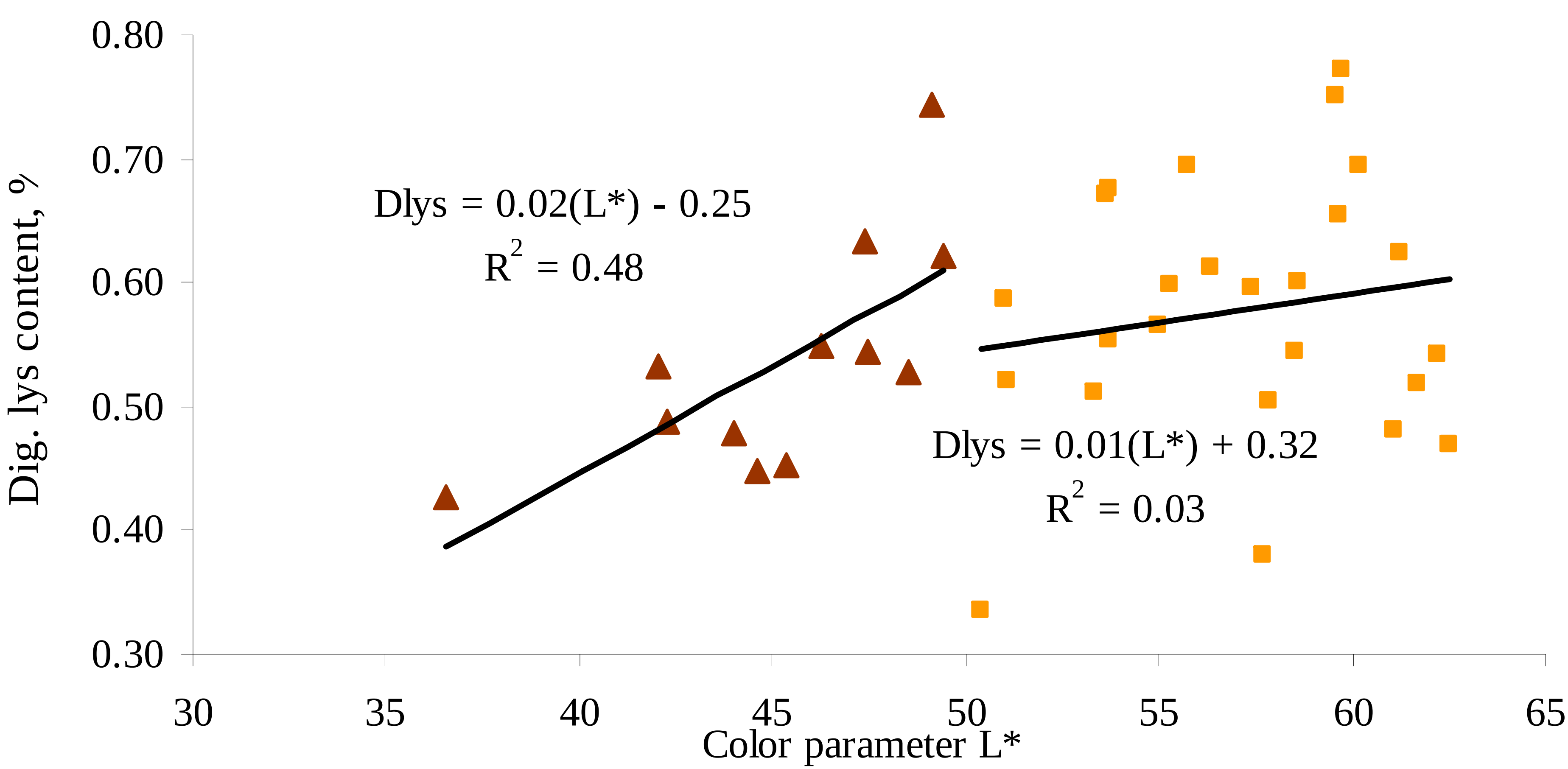
| | Corn | Sorghum | Corn DDGS | Sorghum DDGS |
|---|---|---|---|---|
| Lysine, % | 0.24 | 0.20 | 0.78 | 0.68 |
| Methionine, % | 0.21 | 0.18 | 0.55 | 0.53 |
| Threonine, % | 0.26 | 0.29 | 1.06 | 1.07 |
| Tryptophan, % | 0.09 | 0.07 | 0.21 | 0.35 |
| Valine, % | 0.38 | 0.48 | 1.35 | 1.65 |
| Isoleucine, % | 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



# 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<br>Range<br>0.62-0.87 | 0.73 | 0.25 |
| P Availability, % | 90<br>Range<br>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, 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 |

# 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 | Percentage of Samples Above Lowest FDA Level |
|---|---|---|---|---|---|
| Aflatoxin, ppb | 20 | < 1 | 3.7 | 0.7 | 0 % |
| Deoxynivalenol, 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 | Percentage of Samples Above Lowest FDA Level |
|---|---|---|---|---|---|
| Aflatoxin, ppb | 69 | < 1 | 2.6 | 0.08 | 0 % |
| Deoxynivalenol, 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 | Percentage of Samples Above Lowest FDA Level |
|---|---|---|---|---|---|
| Aflatoxin, ppb | 77 | < 1 | 1.1 | 0.01 | 0 % |
| Deoxynivalenol, 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?

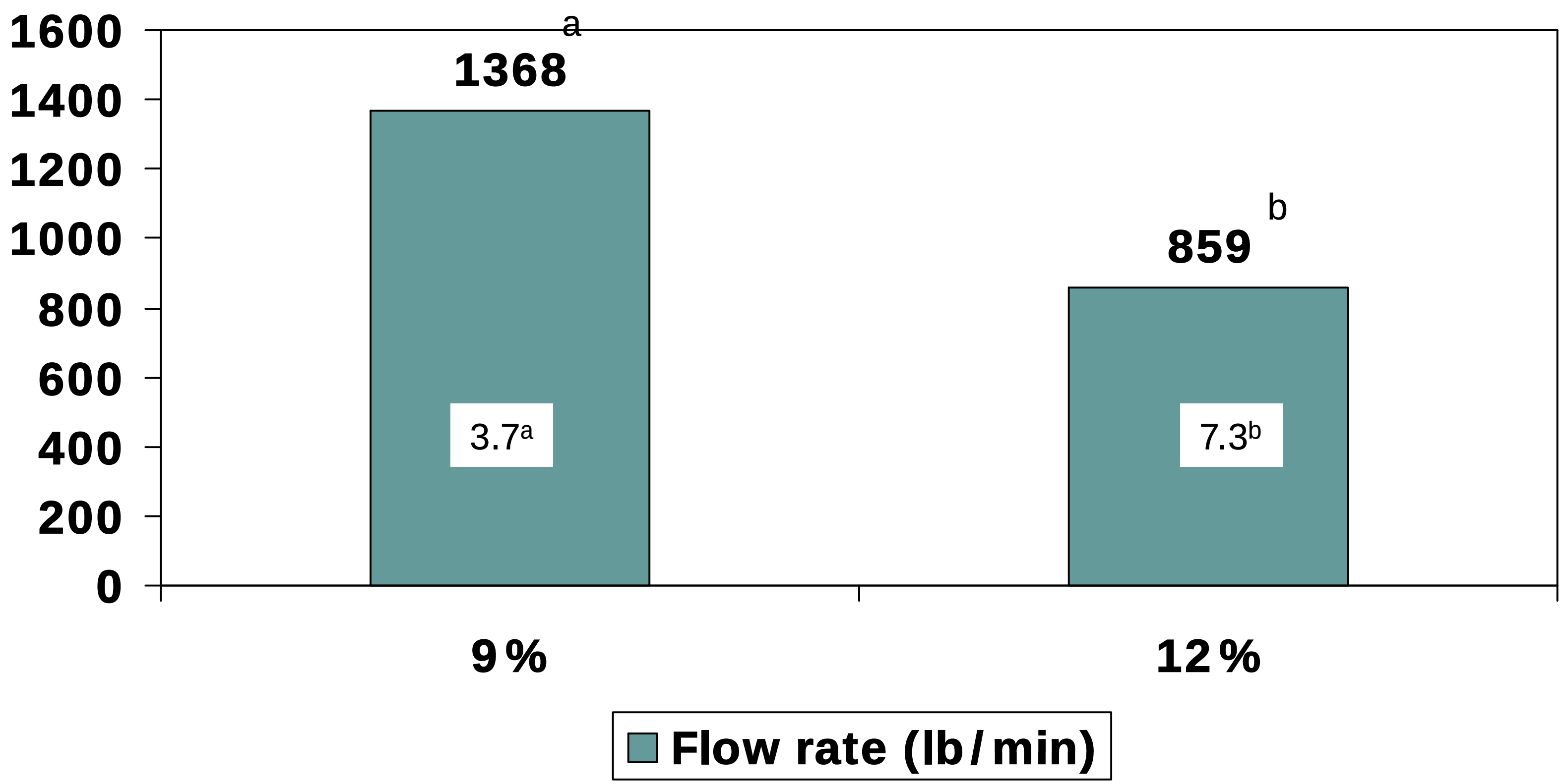
- Virginiamycin (Lactrol) is the only FDA approved antimicrobial for use in ethanol production
  - FDA issued a letter of no objection 11/16/93
  - Added at rate of 2-6 ppm in the fermentation phase
  - Controls bacterial infections
    - Approved swine feed usage rate for Stafac is 5-100 g/ton of feed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

# 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 |

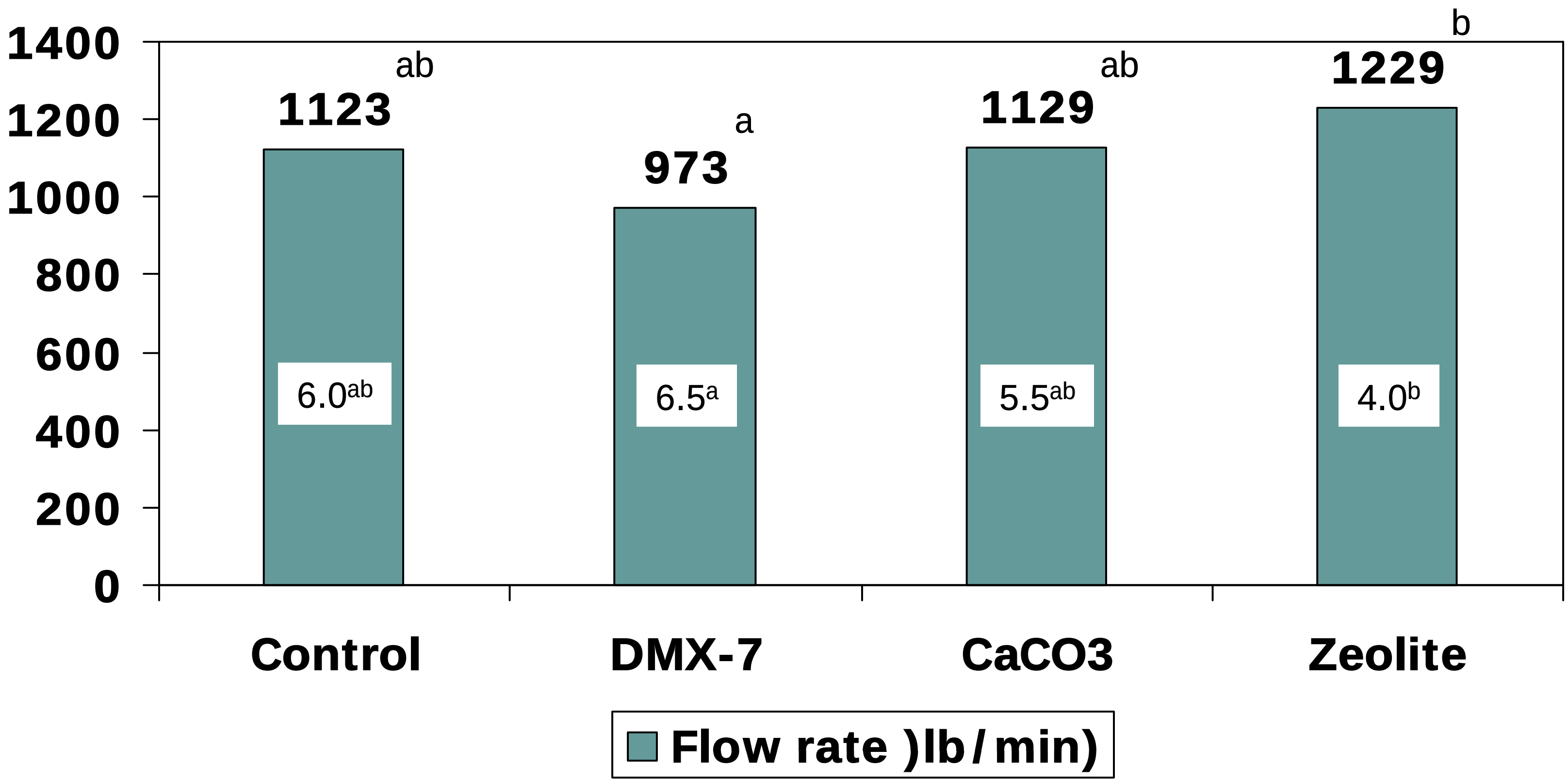
**Peroxide values < 5 mEq/kg are considered acceptable for fat quality and there is no oxidative rancidity.**

# Effect of Moisture Treatments on Flow Rate and Discharge Score




ab(P < 0.05)

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




ab(P < 0.05)

# Feeding DDGS to Grower-Finisher Pigs

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

| Performance Measure | Number of Published Studies | 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., 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)

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

| Performance Measure | Number of Published Studies | Increased | Reduced | Not Changed |
|---|---|---|---|---|
| Dressing Percentage | 18 | 0 | 8 | 10 |
| Backfat, mm | 15 | 0 | 1 | 14 |
| Loin Depth, cm | 14 | 0 | 2 | 12 |
| % Carcass Lean | 14 | 0 | 1 | 13 |

# Muscle Quality Characteristics from Grow-Finish Pigs Fed Diets Containing 0, 10, 20, and 30% DDGS (Whitney et al., 2006)

| 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

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

| Performance Measure | Number of Published Studies | Increased | Reduced | Not Changed |
|---|---|---|---|---|
| Belly thickness, cm | 4 | 0 | 2 | 2 |
| Belly firmness | 3 | 0 | 3 | 0 |
| Iodine value | 8 | 7 | 0 | 1 |

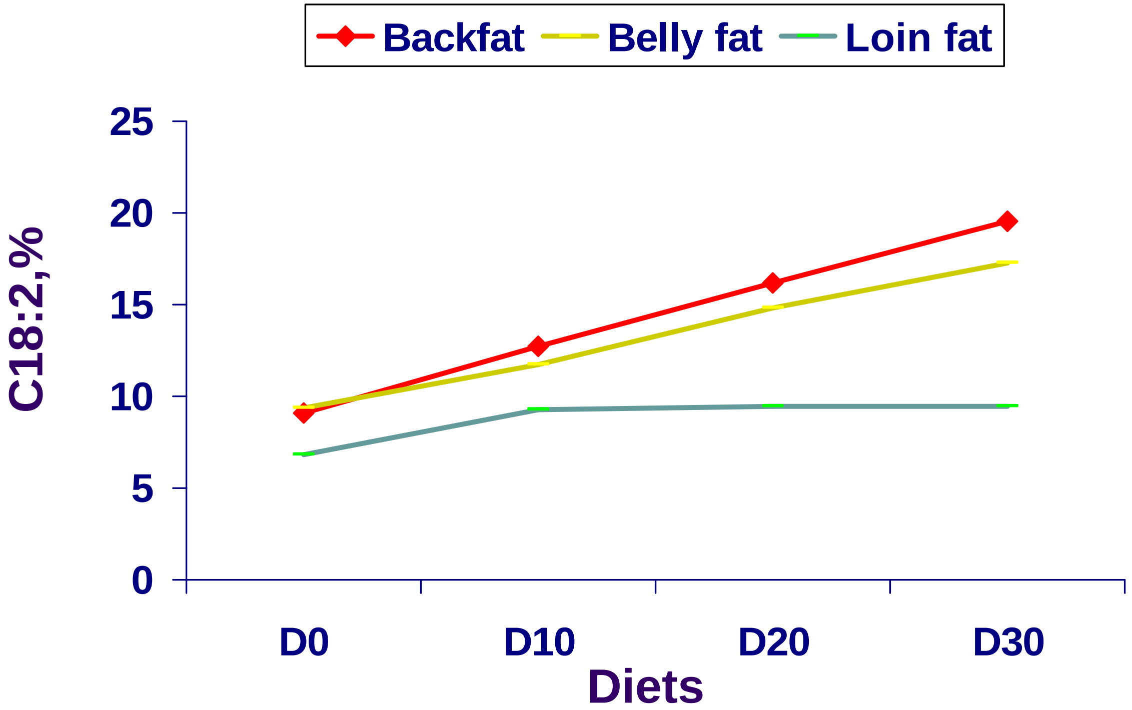
# Comparison of Selected Nutrients in Corn DDGS and Corn (As Fed Basis)

| 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

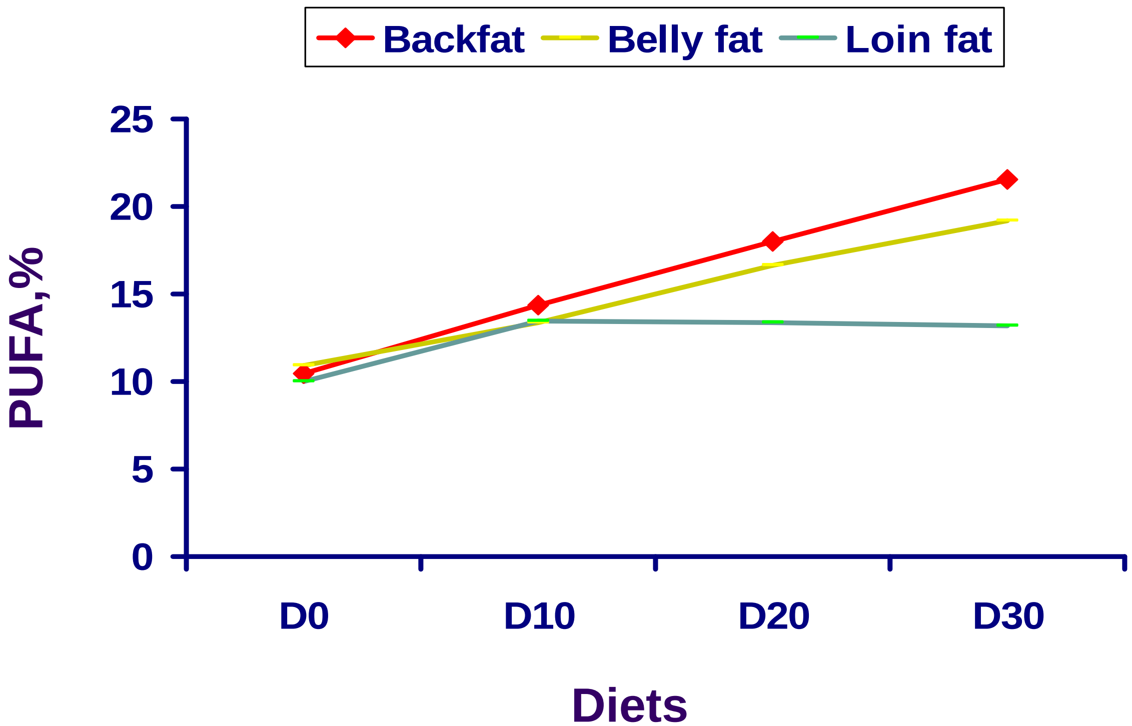
- Based on Iodine Value (IV)
  - ratio of unsaturated:saturated fatty acids
- Maximum IV
  - 70 – Danish Meat Research Institute
  - 72 – National Pork Producers Council
  - 74 – Boyd et al. (1997)
- Various adipose tissue sites are affected differently by dietary fatty acid composition

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



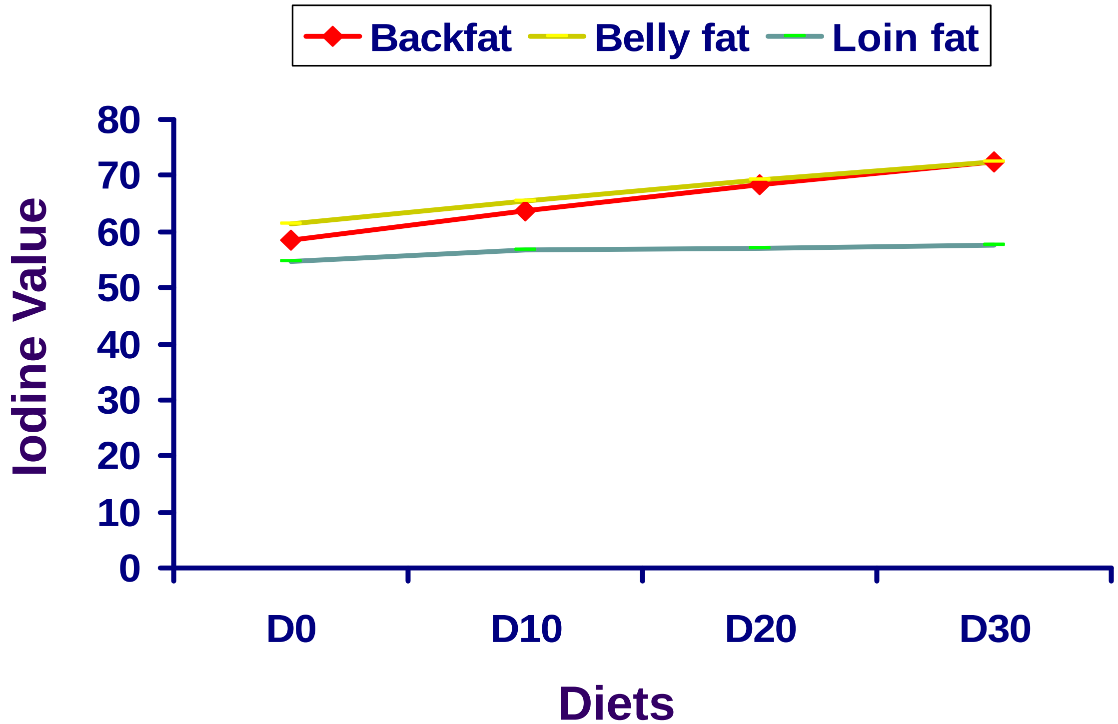

**Linear effect of DDGS level for all fat depot sites ($P < 0.01$)**
**Diet × site ($P < 0.01$)**

# Effect of Dietary DDGS Level on Polyunsaturated Fatty Acid Content of Pork Fat




**Linear effect of DDGS level for backfat and belly fat (P < 0.01)**
**Linear effect of DDGS level for loin fat (P > 0.05)**
**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).**

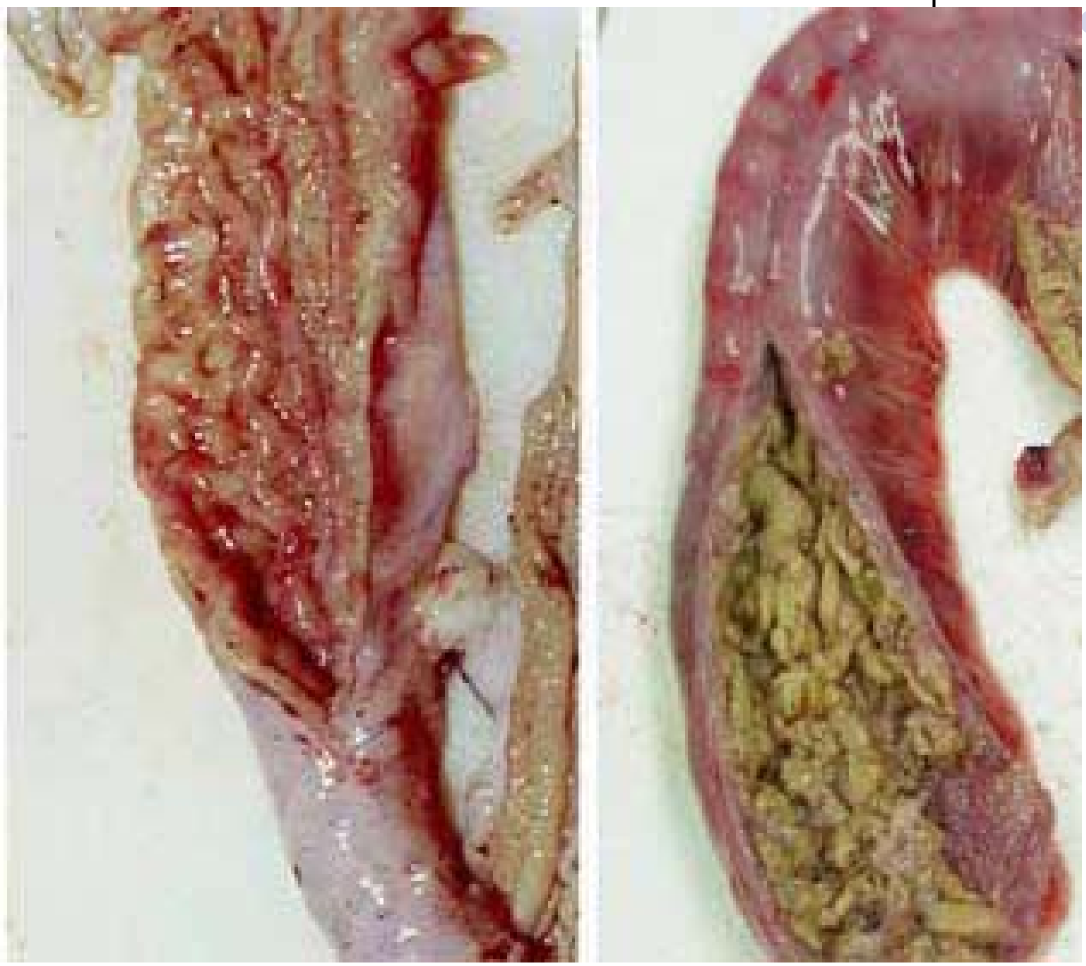
# Summary of the Effects of Feeding DDGS Diets on Pork Quality

- **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**

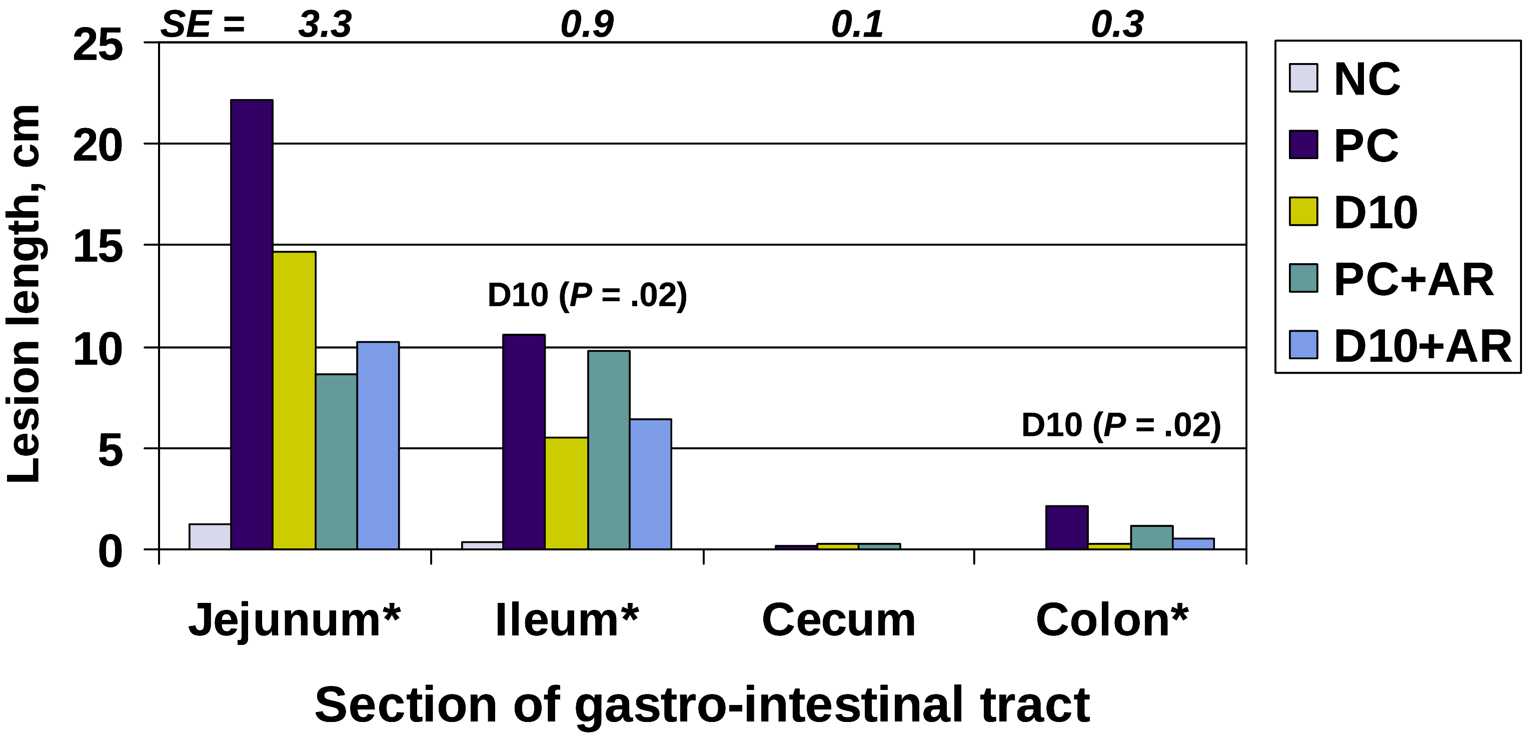
# Does Feeding DDGS Improve Gut Health of Growing Pigs?

## Healthy

## Ileitis

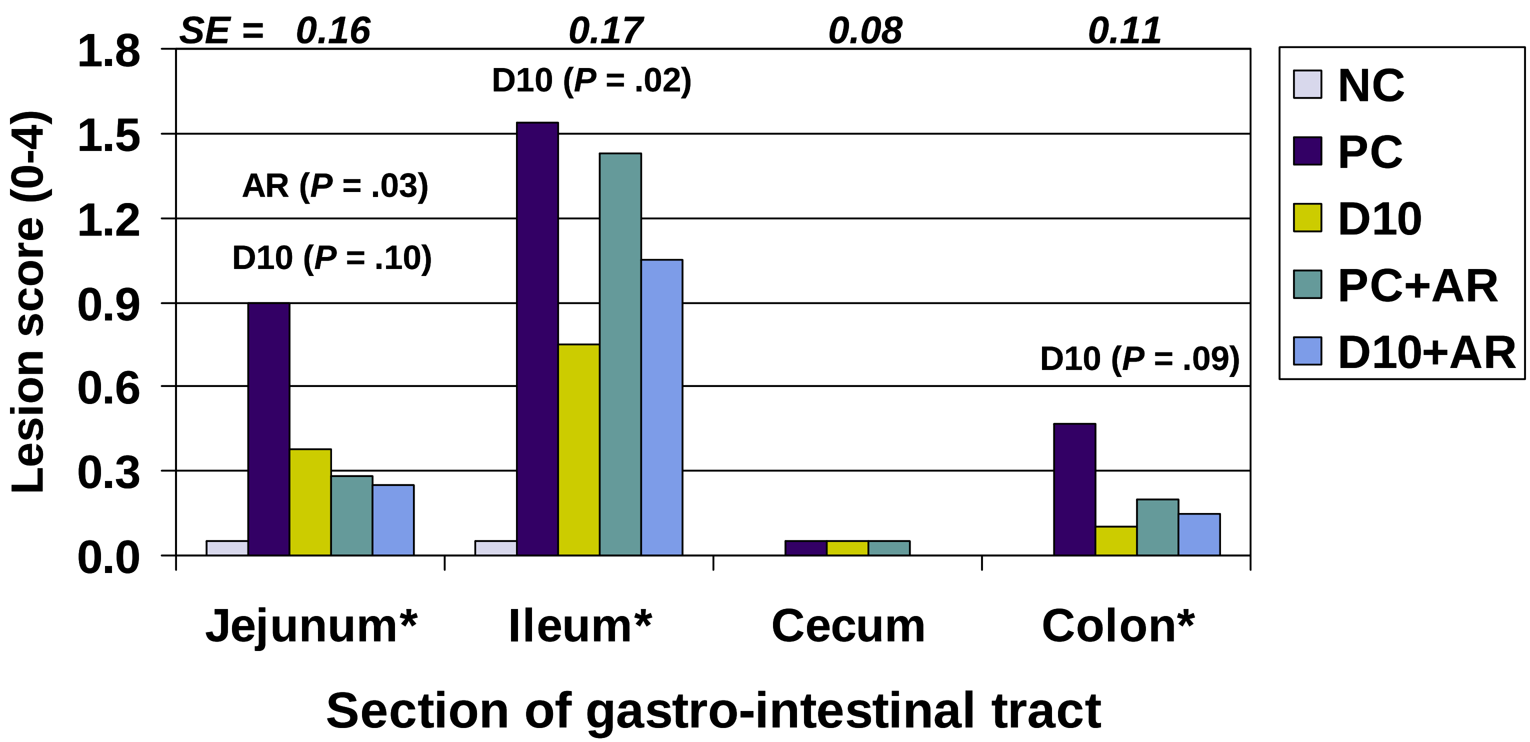


# Effect of Dietary Treatment on Lesion Length (21 d Post-Challenge)



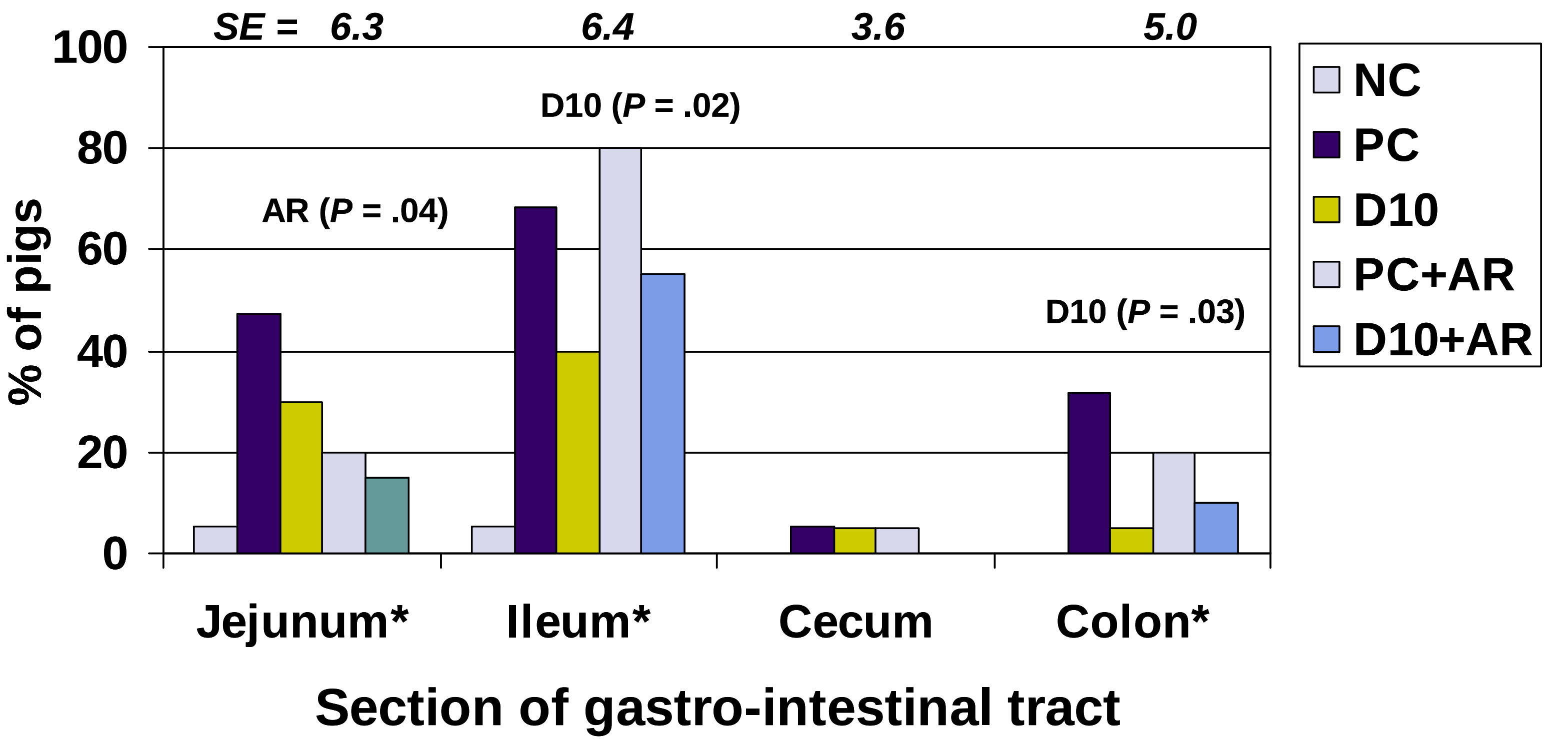

* Effect of disease challenge (*P* < .01).

# 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

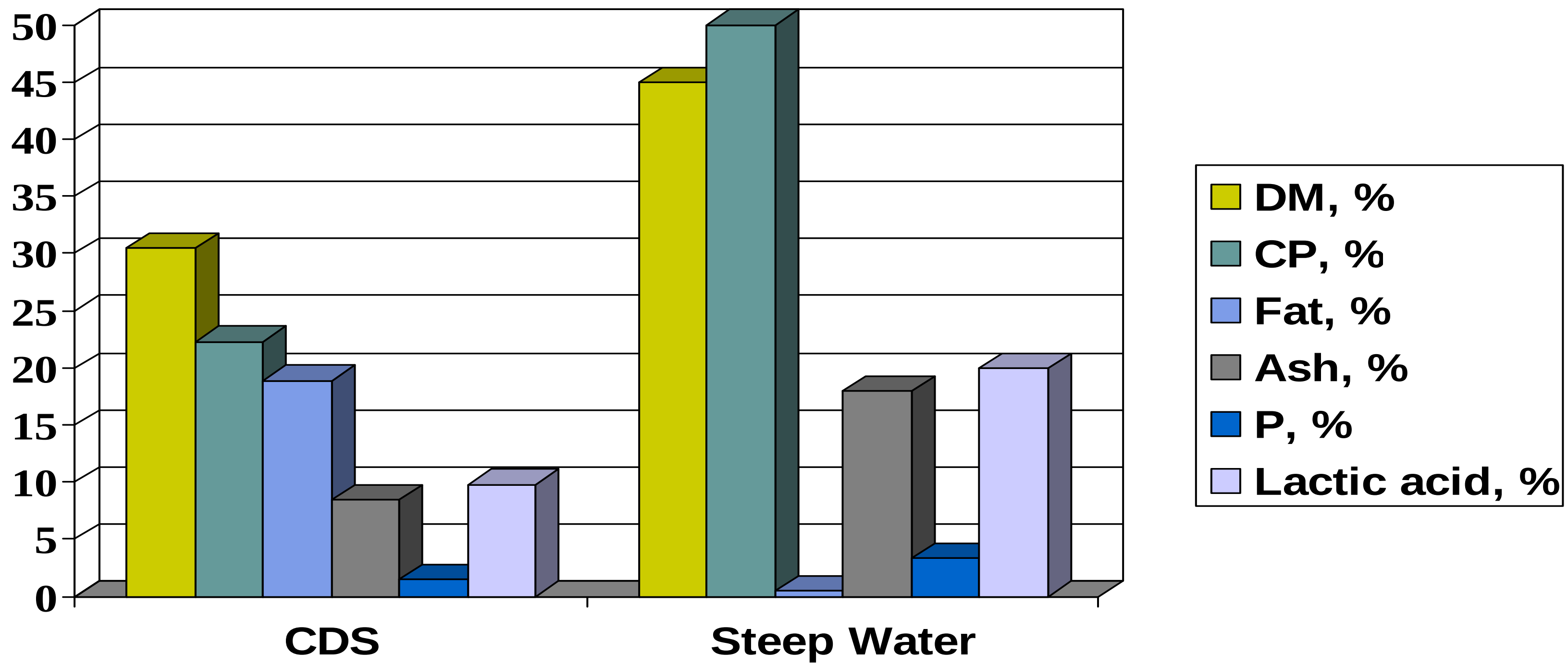
- **Fecal excretion increases**
  - Decrease in dry matter digestibility
- **Urine excretion not affected**
  - No effect on water disappearance
- **N excretion increases**
  - Increased dietary crude protein (N)
  - Minimized by using synthetic amino acids
- **P excretion may vary**
  - Reduced when 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**
- Trend for an increase or no effect on odor detection levels

# Opportunities for Using Liquid Distiller's By-Products

# Benefits of Liquid Feeding vs. Dry Feeding

- Improved nutrient utilization (Jensen and Mikkelsen, 1998)
- Utilize inexpensive liquid by-products (Canibe and Jensen, 2003)
- Reduce environmental impact (Brooks et al., 2001)
- Improve animal performance (Lawlor et al., 2002)
- Enhance gut health (Brooks et al., 2001)
- Reduce the need for feed medications (Canibe and Jensen, 2003)
- Improve animal well-being (Canibe and Jensen, 2003)

# Comparison of the Nutrient Content of Corn Condensed Solubles and Corn Steep Water (100% Dry Matter Basis)



# Nutrient Digestibility of Non-fermented or Fermented Condensed Distillers Solubles (CDS) at 15% Dry Matter (de Lange, 2006).

| | Control | Non-fermented CDS | Fermented CDS |
|---|---|---|---|
| No. pens | 6 | 6 | 6 |
| Initial body wt, kg | 23.5 | 23.3 | 23.4 |
| Energy digestibility, % | 81.6[ab] | 82.5[a] | 79.9[b] |
| Protein digestibility, % | 72.5[a] | 73.2[a] | 69.3[b] |
| Fat digestibility, % | 80.9[b] | 85.4[a] | 85.4[a] |

[a,b] Means within rows with different superscripts differ ($P < 0.05$).

## Growth Performance of Pigs Fed Liquid Diets Containing Non-fermented or Fermented CDS at 15% dry matter (de Lange, 2006).

| | Control | Non-fermented CDS | Fermented CDS |
|---|---|---|---|
| No. pens | 6 | 6 | 6 |
| Initial body wt, kg | 23.5 | 23.3 | 23.4 |
| Final body wt, kg | 50.1[a] | 47.5[b] | 48.6[ab] |
| ADG, g/d | 952[a] | 858[b] | 898[ab] |
| ADFI, kg/d | 1.62[a] | 1.49[b] | 1.61[a] |
| F/G | 1.70 | 1.73 | 1.80 |

[a, b] Means within rows with different superscripts differ ($P < 0.05$).

# Carcass Characteristics of Pigs fed Liquid Diets Containing Non-fermented CDS at 15% dry matter (de Lange, 2006).

| | Control | Non-fermented CDS |
|---|---|---|
| Final body wt, kg | 50.1[a] | 47.5[b] |
| Carcass dressing, % | 82.1 | 82.6 |
| Backfat depth, mm | 16.6 | 17.1 |
| Loin depth, mm | 54.3 | 53.7 |
| Carcass lean yield, kg | 61.1 | 60.9 |
| Loin pH | 5.74[a] | 5.80[b] |
| Loin drip loss, % | 9.63 | 8.83 |

[a, b] Means within rows with different superscripts differ ($P < 0.05$).

## Growth Performance of Pigs Fed Liquid Diets Containing Increasing Levels of Phytase Treated Steep Water (SW; de Lange, 2006).

| | 0% SW | 7.5% SW | 15% SW | 22.5 % SW |
|---|---|---|---|---|
| No. of pens | 4 | 4 | 4 | 4 |
| Initial body wt., kg | 69.1 | 68.8 | 68.8 | 69.3 |
| Final body wt., kg | 108.3 | 104.6 | 107.7 | 103.1 |
| ADG, g/d | $1191^{a}$ | $1080^{a}$ | $1063^{a}$ | $899^{b}$ |
| ADFI, kg/d | $2.76^{a}$ | $2.49^{ab}$ | $2.58^{ab}$ | $2.29^{b}$ |
| F/G | $2.33^{a}$ | $2.30^{a}$ | $2.42^{ab}$ | $2.55^{b}$ |

$^{a,b}$ Means within rows with different superscripts differ ($P < 0.05$).

## Carcass Characteristics of Pigs Fed Liquid Diets Containing Increasing Levels of Phytase Treated Steep Water (SW; de Lange, 2006).

| | 0% SW | 7.5% SW | 15% SW | 22.5 % SW |
|---|---|---|---|---|
| No. of pens | 4 | 4 | 4 | 4 |
| Final body wt., kg | 108.3 | 104.6 | 107.7 | 103.1 |
| Carcass wt., kg | 86.3 | 82.7 | 83.4 | 80.5 |
| Loin depth, mm | 58.2 | 58.9 | 56.4 | 58.3 |
| Backfat depth, mm | 18.1 | 18.7 | 18.0 | 17.1 |
| Lean yield, % | 60.3 | 60.3 | 60.5 | 60.1 |

[a,b] Means within rows with different superscripts differ ($P < 0.05$).

# 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