Inclusion of Distillers Dried Grains with Solubles (DDGS) in Nursery Pig Diets

Distiller’s Dried Grains with Solubles (DDGS)

- Feeding recommendations for nursery pigs:
  - 5% maximum inclusion (Newland and Mahan, 1990)
    - Higher fiber content
    - Lower energy density
    - Poor amino acid profile, digestibility, and variability
  - Based on:
    - A few outdated studies (+25 years old)
    - DDGS from conventional sources
      - Ethanol
      - Beverage

Recent DDGS Research

- “New generation” DDGS vs. reference values (NRC, 1998):
  - Less variability of nutrients (Spiehs et al., 2002)
  - Increased metabolizable energy (Spiehs et al., 1999)
  - Greater digestible amino acid levels (Whitney et al., 2000)
  - Improved phosphorus availability (Whitney et al., 2001)

- DDGS from “new generation” ethanol plants:
  - Is of high nutritional quality
  - Should serve as an acceptable partial substitute for corn, soybean meal, and dicalcium phosphate in nursery diets

Objectives

- Evaluate the effect of including increasing levels of DDGS from “new generation” ethanol plants in nursery diets on growth rate, feed intake, and feed efficiency
- Determine the maximum inclusion rate of “new generation” DDGS in nursery diets

Methodology

- 2 growth performance experiments
- 0, 5, 10, 15, 20, or 25% DDGS in nursery diet
- 96 pigs in each experiment
  - Blocked by gender and ancestry, then randomly allotted within each block
  - 4 pigs/pen (0.37 m²/pig)
  - 4 pens/dietary treatment
- 3-phase feeding program
  - Phase 1: commercial, pelleted diet fed first 4 d post-weaning
  - Phase 2: fed for 14 d, meal form
  - Phase 3: fed for 21 d, meal form

Nursery Phase 2 Diets*

<table>
<thead>
<tr>
<th>Ingredient, %</th>
<th>DDGS inclusion level, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Corn</td>
<td>50.1</td>
</tr>
<tr>
<td>Soybean meal (47% CP)</td>
<td>23.4</td>
</tr>
<tr>
<td>DDGS</td>
<td>0</td>
</tr>
<tr>
<td>Whey, dried</td>
<td>15.0</td>
</tr>
<tr>
<td>Fish meal, select menhaden</td>
<td>0.8</td>
</tr>
<tr>
<td>Choice white grease</td>
<td>3.5</td>
</tr>
<tr>
<td>Dicalcium phosphate</td>
<td>1.2</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.4</td>
</tr>
<tr>
<td>Other</td>
<td>1.3</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
</tr>
</tbody>
</table>

* Diets formulated to contain: 3340 kcal/kg ME, 1.35% AID Lys, 0.08% AID MedCyn, 0.95% Ca, 0.80% P
Nursery Phase 3 Diets

<table>
<thead>
<tr>
<th>Ingredient, %</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
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</thead>
<tbody>
<tr>
<td>Corn</td>
<td>61.5</td>
<td>57.0</td>
<td>52.3</td>
<td>47.8</td>
<td>43.2</td>
<td>38.7</td>
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<tr>
<td>Soybean meal (47% CP)</td>
<td>32.6</td>
<td>32.2</td>
<td>31.8</td>
<td>31.4</td>
<td>30.9</td>
<td>30.5</td>
</tr>
<tr>
<td>DDGS</td>
<td>0.0</td>
<td>5.0</td>
<td>10.0</td>
<td>15.0</td>
<td>20.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Choice white grease</td>
<td>2.4</td>
<td>2.4</td>
<td>2.5</td>
<td>2.5</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Limestone</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Other</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
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<td>100.0</td>
</tr>
</tbody>
</table>

* Diets formulated to contain: 3390 kcal/kg ME 1.15% AID Lys 0.65% AID Met+Cys 0.60% Ca 0.70% P

**Experiment 1**

- **Pigs:**
  - Weaned at 19 d of age
  - Weighed 7.1 kg body weight
- **Pig weight and feed consumption:**
  - Measured for each phase
- **Statistics**
  - Utilized GLM procedure of SAS with repeated measures in time
  - Pen = experimental unit
  - Orthogonal comparisons to determine linear, quadratic, and/or cubic responses to increasing DDGS level in the diet

**Effect of DDGS Level on Growth Rate, Exp. 1**

<table>
<thead>
<tr>
<th>Phase</th>
<th>ADG (g/d)</th>
<th>0% DDGS</th>
<th>5% DDGS</th>
<th>10% DDGS</th>
<th>15% DDGS</th>
<th>20% DDGS</th>
<th>25% DDGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>SE = 33.8</td>
<td>a, b</td>
<td>a, b</td>
<td>a, b</td>
<td>a, b</td>
<td>a, b</td>
<td>a, b</td>
</tr>
<tr>
<td>3</td>
<td>SE = 42.1</td>
<td>a, b</td>
<td>a, b</td>
<td>a, b</td>
<td>a, b</td>
<td>a, b</td>
<td>a, b</td>
</tr>
</tbody>
</table>

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

**Effect of DDGS Level on Feed Intake, Exp. 1**

<table>
<thead>
<tr>
<th>Phase</th>
<th>ADFI (g/d)</th>
<th>SE = 46.9</th>
<th>SE = 82.6</th>
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</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Effect of DDGS Level on Feed Efficiency, Exp. 1**

<table>
<thead>
<tr>
<th>Phase</th>
<th>G/F</th>
<th>SE = 0.11</th>
<th>SE = 0.06</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Effect of DDGS Level on Final Body Weight, Exp. 1**

<table>
<thead>
<tr>
<th>Dietary treatment</th>
<th>Body weight, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>30</td>
</tr>
</tbody>
</table>

SE = 1.4
### Summary of Results – Exp. 1

- No effect of increasing dietary DDGS level on:
  - Growth rate
  - Feed intake
  - Feed efficiency
  - Final nursery weight
- Pigs were able to effectively consume and convert high levels of DDGS (up to 25%) without any apparent adverse effects on growth

### Experiment 2

- Pigs:
  - Weaned at 16.9 d of age
  - Weighed 5.3 kg body weight
- Pig weight and feed consumption:
  - Measured for each phase
- Statistics
  - Utilized GLM procedure of SAS with repeated measures in time
  - Pen = experimental unit
  - Orthogonal comparisons to determine linear, quadratic, and/or cubic responses to increasing DDGS level in the diet

#### Effect of DDGS Level on Growth Rate, Exp. 2

<table>
<thead>
<tr>
<th>Diet Level</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25% DDGS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

#### Effect of DDGS Level on Feed Intake, Exp. 2

<table>
<thead>
<tr>
<th>Diet Level</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20% DDGS</td>
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<td></td>
</tr>
<tr>
<td>25% DDGS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

#### Effect of DDGS Level on Feed Efficiency, Exp. 2

<table>
<thead>
<tr>
<th>Diet Level</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20% DDGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25% DDGS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Effect of DDGS Level on Final Body Weight, Exp. 2

<table>
<thead>
<tr>
<th>Diet Level</th>
<th>Body weight, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% DDGS</td>
<td></td>
</tr>
<tr>
<td>5% DDGS</td>
<td></td>
</tr>
<tr>
<td>10% DDGS</td>
<td></td>
</tr>
<tr>
<td>15% DDGS</td>
<td></td>
</tr>
<tr>
<td>20% DDGS</td>
<td></td>
</tr>
<tr>
<td>25% DDGS</td>
<td></td>
</tr>
</tbody>
</table>

Means not sharing a common superscript letter are significantly different ($P < .05$).
Summary of Results – Exp. 2

- Increasing level of DDGS during Phase 2:
  - Decreased feed intake
  - Tended to decrease growth rate
  - No effect of feed efficiency
- No effect of DDGS on ADG, ADFI, or G/F during Phase 3
- No effect of DDGS on ending nursery body weight

Implications

- DDGS from “new generation” ethanol plants is an acceptable partial substitute for corn, soybean meal, and dicalcium phosphate in nursery diets
  - Formulate diets on ME and digestible amino acid basis
  - Can include up to 25% DDGS in Phase 3 with no detrimental effects on growth performance
  - In younger, lighter pigs, including greater than 5% DDGS in Phase 2 may decrease feed intake and subsequent growth rate
    - No detrimental effect in older, heavier pigs
    - No difference in body weight at end of the nursery period

Effect of Dietary Corn Distiller’s Dried Grains with Solubles (DDGS) on the Ability of Growing Pigs to Resist Ileitis

Ileitis

- Porcine Proliferative Enteropathy
- Caused by Lawsonia intracellularis
  - gram negative microaerophil bacteria
  - infects immature epithelial cells located in the crypts of the lower small intestine
  - inhibits maturation of cells, resulting in cells multiplying without being sloughed off
  - affects other species of animals
    - rabbits, deer, horses, ostrich, hamsters (Cooper et al., 1997)

Healthy vs. Ileitis images
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
- Height of lesions around 21 days post-infection

Pigs affected: (Glock et al., 1994)
- 40-100 lb growing pigs
- Bred gilts
- Sows and boars
- Finishing pigs

Field reports from a number of pork production operations have indicated:
- Including 5 to 10% DDGS to grow-finish diets in ileitis swine herds
  - Improved performance
  - Reduced mortality (> 50%)
  - Ability to remove part or all of sub-therapeutic antibiotics without ileitis outbreak
- Similar results have been reported with using soybean hulls

DDGS contains low levels of soluble (0.7%) and high levels of insoluble (42.2%) fiber (Shurson et al., 2000)
- Low soluble fiber diets may reduce the proliferation of pathogenic organisms in the GI tract (Hampson, 1999)
  - Reduced pathogen substrate availability?
  - Fiber may influence the secretory function of the epithelium, which are implicated with bacterial adhesion (Smith and Halls, 1968)
  - May have a “cleansing” effect in gut through changes by reducing the viscosity of digesta (Lawrence, 1972)
- DDGS contains yeast cells
  - May have nutraceutical properties

Feed

Exp. Diets

Fecal

Fecal

Wean

Allot

Challenge

Necropsy

Methodology – Experiment 1

Methodology – Experiment 1

Pigs:
- Weaned at 17 d of age
- Blocked by gender and weight
- Fed experimental diets for 7 weeks

Dietary treatments:
- NC: Negative control, corn-soybean meal diet
- PC: Positive control, corn-soybean meal diet*
- D10: 10% DDGS diet*
- D20: 20% DDGS diet*
- Diets formulated to contain: 3390 kcal/kg ME, 1.15% AID lysine, 0.65% AID methionine & cystine, 0.80% Ca, and 0.70% P
Methodology – Experiment 1

- Statistical analysis:
  - Utilized the GLM procedure of SAS (ANOVA and LSMeans)
  - Compared NC and PC treatments (effect of challenge)
  - Analyzed within challenged groups (effect of diet)
  - Individual pig = experimental unit

Effect of Dietary DDGS Level on Lesion Length, d 21 Post-Challenge, Exp. 1

Effect of Dietary DDGS Level on Lesion Severity, d 21 Post-Challenge, Exp. 1

Effect of Dietary DDGS Level on Lesion Prevalence, d 21 Post-Challenge, Exp. 1

Effect of Dietary DDGS Level on Fecal Shedding (PCR Analysis), Exp. 1

Effect of DDGS Level on *L. intracellularis* Infection (IHC Analysis), Exp. 1
Summary of Results – Exp. 1

- DDGS inclusion did not improve the pig’s ability to resist an ileitis challenge
- Dosage (inoculation) rate was higher than desired
  - Actual: $1.56 \times 10^8$ dose of \textit{L. intracellularis}
  - Goal: $1 \times 10^8$ dose of \textit{L. intracellularis}

Methodology - Experiment 2

- Dietary treatments:
  - NC: Negative control corn-soybean meal diet, no antimicrobial
  - PC: Positive control corn-soybean meal diet, no antimicrobial
  - D10: 10% DDGS diet, no antimicrobial
  - PC+AR: Control diet with antimicrobial regimen
  - D10+AR: DDGS diet with antimicrobial regimen
- Antimicrobial regimen (AR):
  - Bacitracin Methylene Disalicylate (BMD®)
  - Chlortetracycline (Aureomycin®)
- Statistical analysis:
  - Compared NC and PC treatments (effect of challenge)
  - Factorial (2x2) arrangement of challenged treatments
Effect of Treatment on *L. intracellularis* Infection (IHC Analysis), Exp. 2

- IHC Score*
- IHC Prevalence*

Summary of Results, Exp. 2

- Inoculation level was closer to goal
  - 8.0 x 10^8 *L. intracellularis*/pig
- DDGS inclusion (10%) or antimicrobial regimen had a positive effect on the pig’s ability to resist an ileitis challenge
- No beneficial additive effects of combining DDGS and BMD®/Aureomycin® regimen

Methodology - Experiment 3

- Dietary treatments:
  - NC: Negative control corn-soybean meal diet, no antimicrobial
  - PC: Positive control corn-soybean meal diet, no antimicrobial*
  - D10: 10% DDGS diet
  - SH: 5% soybean hulls diet
  - PA: Polyclonal antibody spray-dried on soybean hulls (5%)
- Statistical analysis:
  - Utilized the GLM procedure of SAS (ANOVA and LSMeans)
    - Compared NC and PC treatments (effect of challenge)
    - Analyzed within challenged groups (effect of diet)
    - Individual pig = experimental unit

Effect of Dietary Treatment on Lesion Length, d 21 Post-Challenge, Exp. 3

- Jejunum* Ileum* Cecum Colon*
- Lesion length, cm

Effect of Dietary Treatment on Lesion Severity, d 21 Post-Challenge, Exp. 3

- Jejunum* Ileum* Cecum Colon*
- Lesion score (0-4)

Effect of Dietary Treatment on Lesion Prevalence, d 21 Post-Challenge, Exp. 3

- Jejunum* Ileum* Cecum Colon*
- % of pigs

* Effect of disease challenge (P < .01).
Effect of Dietary Treatment on Fecal Shedding (PCR Analysis), Exp. 3

Effect of Treatment on *L. intracellularis* Infection (IHC Analysis), Exp. 3

**Summary of Results, Exp. 3**

- Inoculation level was similar to Experiment 2 (8.0 x 10⁸)
  - Much more severe ileitis challenge, however:
    - Experiment 2
      - Total lesion length: 35 cm
      - Lesion severity (ileum): 1.54
      - Total lesion prevalence: 70%
      - Fecal shedding (PCR): 68% (d21)
    - Experiment 3
      - Total lesion length: 98 cm
      - Lesion severity (ileum): 1.85
      - Total lesion prevalence: 85%
      - Fecal shedding (PCR): 90% (d14)
- No beneficial effects of 10% DDGS or 5% soybean hulls inclusion, or feeding polyclonal antibody product

**Implications**

- Dietary inclusion of DDGS
  - May provide some benefit during moderate ileitis challenge
  - May not provide a detectable benefit during a severe ileitis challenge
- Disease challenge model
  - Mucosal homogenate provides variable response
    - Use of pure culture may provide more predictable responses
  - Inoculation level must be reduced (1 x 10⁸ or less)