Welcome to the Lunchtime Webinar Series: Serving Pennsylvania’s Best Practices on Animal Ag, Water-, and Air Quality.

AIR QUALITY – Nutrition and Ammonia Emissions

- **Alex Hristov**, PSU Department of Dairy and Animal Sciences
- **Paul Patterson**, PSU Department of Poultry Science
- **Alan Rotz**, USDA Agricultural Research Service

HOST: Kristen Saacke Blunk
Penn State Agriculture & Environment Center
Extension State Program Leader for Air & Water
Feeding Strategies to Reduce Nitrogen Losses and Ammonia Emissions from Dairy Cows

Alexander N. Hristov
Department of Dairy and Animal Science
Pennsylvania State University
New EPA ammonia regulation

- Starting Jan 20, 2009, CAFOs with 700 or more mature dairy cows must notify state and local emergency response officials if they emit 100 pounds or more of ammonia or hydrogen sulfide in any 24-hour period

- Ammonia emission worksheet:
  - lower bound (lb/d) = lowest head count $\times$ 0.028 (lb/hd/d; winter emission rate)
  - Upper bound (lb/d) = lowest head count $\times$ 0.07 (lb/hd/d; summer emission rate)
  - Example: 1,000 cows $\times$ 0.07 = 70 lb ammonia per day
Livestock contribution to ammonia emissions in the U.S.

- Livestock: 51%
- Industrial processes: 28%
- Transportation
- Fertilizer application
- Other

Half from ruminants

Roy Huntley, EPA, personal communication
Environmental effects of ammonia

- Ammonia emitted from manure can be converted rapidly to ammonium ($\text{NH}_4^+$) aerosol by reactions with nitric and sulfuric acids.

- Once removed from the atmosphere, $\text{NH}_4^+$ contributes to:
  - Ecosystem fertilization
  - Acidification
  - Eutrophication

- As an aerosol, $\text{NH}_4^+$ contributes directly to PM2.5 formation and can impact human health:
  - Cardiovascular and respiratory diseases, lung cancer

- Overall, ammonia emitted from manure can impact:
  - Atmospheric visibility, soil acidity, forest productivity, terrestrial ecosystem biodiversity, stream acidity, coastal productivity, biodiversity of terrestrial ecosystems

NRC, 2003
Chemistry of PM2.5 formation from ammonia

SO₂ → H₂SO₄
NO₂ → HNO₃

Ammonia

(NH₄)₂SO₄ or (NH₄)HSO₄
NH₄NO₃

PM2.5

Rob Pinder, EPA, personal communication
The direct impact of livestock on PM2.5 and PM10 formation is negligible
- 0.03% of PM2.5
- 0.02% of PM10

- All NH\textsubscript{3} emitted will form nitrate or sulfates (on molar basis)

- 51% of ammonia is emitted from livestock

Hristov, 2009

Analysis of livestock contribution to PM2.5 concentration

EPA (2008) PM2.5 concentration data
(sulfate, nitrate, elemental and organic carbon, crustal material)
Livestock contribution to PM2.5 concentration

From 7 to 21%

Rainy weather (Oct-Apr)

PM2.5, µg/m³

Northwest: 2.25
Northcentral: 2.05
Midwest: 2.15
Northeast: 1.43
Southeast: 0.78
Southcentral CA: 2.46

Warm weather (May-Sept)

PM2.5, µg/m³

Northwest: 0.23
Northcentral: 0.63
Midwest: 1.35
Northeast: 1.00
Southeast: 1.15
Southcentral CA: 1.74

On average, 9 (if ammonium bisulfate is formed) to 11% (if ammonium sulfate is formed) contribution

Penn State College of Agricultural Sciences

Dairy & Animal Science
Feeding strategies to improve the efficiency of utilization of dietary N and reduce ammonia emissions from manure
Efficiency of utilization of feed N in Holstein dairy cows (846 diets)

Hristov et al., 2005

Feed to milk N conversion ratio

SE=0.04
Hristov’s experiments

Examples of high and low MNE

Low MNE

CP = 18%
MY = 23 kg
MNE = 15%

High MNE

CP = 16%
MY = 46 kg
MNE = 30%
Hristov & Huhtanen, 2008

Effect of dietary crude protein on milk yield and milk N efficiency (simulation based on 1,700 diets)

\[
\text{MY (kg/d)} = 21.47 + 0.595 \times \text{CP (\%)} \\
\text{MNE (\%)} = 47.04 - 1.253 \times \text{CP (\%)}
\]
Hristov & Huhtanen, 2008

Effect of dietary crude protein on N losses (simulation based on 1,700 diets)

1%‐unit increase in dietary CP will result in 2.8 g/d increase in milk N output and 35.7 g/d N lost with feces and urine.

\[ N \text{ not secreted in milk (kg/d)} = -0.157 + 0.035 \times \text{CP (\%)} \]
Dietary crude protein effect on ammonia emissions
Colmenero and Broderick, 2006

Effect of crude protein on urinary urea excretion

Milk yield was not affected 36-37 kg/d; P > 0.05

P < 0.001, linear
N losses in the ruminant – volatility of excreted N

Losses with urine – approx. 63% of all N losses
50-90% is urea N
66-70% may be lost as ammonia

Losses with feces – approx. 37% of all N losses
Only 1-13% may be lost as ammonia
Typical ammonia emission pattern in vitro

Lee et al., unpublished
About 50% of the estimated N output with feces and urine was unaccounted for in manure in 24 h.
Crude protein levels experiment

<table>
<thead>
<tr>
<th>Composition (DM)</th>
<th>Control</th>
<th>LowCP</th>
<th>ExLowCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein, %</td>
<td>17.6</td>
<td>15.2</td>
<td>14.4</td>
</tr>
<tr>
<td>NEL, Mcal/kg</td>
<td>1.55</td>
<td>1.51</td>
<td>1.51</td>
</tr>
<tr>
<td>NDF, %</td>
<td>30</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>Forage NDF</td>
<td>25</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>NFC, %</td>
<td>44</td>
<td>46</td>
<td>46</td>
</tr>
<tr>
<td>MP balance, g/d</td>
<td>+15</td>
<td>+16</td>
<td>+18</td>
</tr>
<tr>
<td>RDP balance, g/d</td>
<td>+570</td>
<td>+1</td>
<td>-369</td>
</tr>
</tbody>
</table>

Agle et al., 2008
Effect on N intake and urinary excretion

Agle et al., 2008
Cumulative ammonia losses from manure as affected by diet CP

Agle et al., 2008

Cumulative ammonia N loss, mg

Incubation day

Lines: $P = 0.04 \& < 0.001$

38%
Cumulative ammonia losses from manure as affected by diet CP

Lee et al., unpublished

Lines, P < 0.001

47%
Protein and energy interaction

Van der Stelt et al., 2008; non-lactating cows

Ammonia emissions significantly decreased with **decreasing** CP concentration and **increasing** energy density of the diet.
When the requirements of the cow for AA are not met, production suffers

Lee et al., unpublished

3 kg less
SE = 1.08
P = 0.04

16% CP

14% CP

SE = 0.60
P = 0.26
Dietary energy effects on ammonia emissions
Energy density experiment

<table>
<thead>
<tr>
<th>Composition (DM)</th>
<th>Control</th>
<th>High-energy diet</th>
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</thead>
<tbody>
<tr>
<td>Forage, %</td>
<td>50</td>
<td>17</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>17.9</td>
<td>17.8</td>
</tr>
<tr>
<td>RDP, %</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>NEL, Mcal/kg</td>
<td>1.65</td>
<td>1.83</td>
</tr>
<tr>
<td>NDF, %</td>
<td>32</td>
<td>25</td>
</tr>
<tr>
<td>Forage NDF</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td>NFC, %</td>
<td>39</td>
<td>47</td>
</tr>
</tbody>
</table>
Cumulative ammonia losses from manure

Agle et al., 2008
Take-home message

- Dietary CP is the most important single factor determining milk N efficiency
  - Rumen N balance should be reduced to improve N efficiency
- Feeding diets with lowered CP & ruminally-degradable protein concentrations consistently results in decreased urinary N excretion and in several studies have decreased cumulative ammonia losses from manure
- In one study, increasing energy density of the diet reduced ruminal ammonia concentration and relative urinary N losses, but had no effect on cumulative ammonia losses from manure
Manure du Jour
Poultry Nutrition Aimed at Improving Air Quality (NH₃)

Paul Patterson, Department of Poultry Science, Penn State University
Hen Mass Balance
Nitrogen Partitioning

Feed Nitrogen = 100%

- 34.1% Manure-N
- 25.0% Carcass-N
- 40.0% Gaseous-N
- 0.8% Egg-N

Patterson & Lorenz, 1996
Partitioning of Feed Nitrogen in Commercial Poultry

<table>
<thead>
<tr>
<th>Poultry</th>
<th>Feed %</th>
<th>Manure or litter</th>
<th>Carcass</th>
<th>Eggs</th>
<th>Atmosphere</th>
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</thead>
<tbody>
<tr>
<td>Laying hens</td>
<td>100</td>
<td>25.01</td>
<td>0.84</td>
<td>34.07</td>
<td>40.01</td>
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<tr>
<td>Pullets</td>
<td>100</td>
<td>43.20</td>
<td>25.30</td>
<td>----</td>
<td>31.50</td>
</tr>
<tr>
<td>Turkeys</td>
<td>100</td>
<td>28.00</td>
<td>46.00</td>
<td>----</td>
<td>26.00</td>
</tr>
<tr>
<td>Broilers</td>
<td>100</td>
<td>30.56</td>
<td>51.08</td>
<td>----</td>
<td>18.36</td>
</tr>
</tbody>
</table>

PM2.5 Non-attainment Counties

PM2.5 Nonattainment State Recommendations
- Nonattainment
- Partial nonattainment
- EPA Additions

Nonattainment
Partial nonattainment
EPA Additions
Unclassifiable
Attainment/Unclassifiable
PM2.5 Non-Attainment Counties

EPA Designation
- Attainment/Unclassifiable
- Nonattainment - Whole County
- Nonattainment - Partial County
Dietary Strategies for Nitrogen

1. Formulate on amino acids (AA) not CP
# Impact of Supplemental Amino Acids on Dietary Protein and Amino Acid Level – Layer Peaking Diet

<table>
<thead>
<tr>
<th>Available Supplemental Amino Acids</th>
<th>Diet Target</th>
<th>Met, Lys, Thr.</th>
<th>Met, Lys,</th>
<th>Met.</th>
<th>None</th>
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</thead>
<tbody>
<tr>
<td>%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crude Protein</td>
<td></td>
<td>18.22</td>
<td>18.61</td>
<td>19.01</td>
<td>29.28</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.82</td>
<td>0.82</td>
<td>0.82</td>
<td>0.82</td>
<td>1.43</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
<td>0.40</td>
<td>0.35</td>
</tr>
<tr>
<td>Met+Cys</td>
<td>0.69</td>
<td>0.71</td>
<td>0.72</td>
<td>0.72</td>
<td>0.80</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.61</td>
<td>0.61</td>
<td>0.61</td>
<td>0.63</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Source: Michael Elliot, Wenger Feeds, Rheems, PA
## Impact of Supplemental Amino Acids on Diet Protein and Cost - Layer Peaking Diet

<table>
<thead>
<tr>
<th>Supplemental Amino Acids</th>
<th>Met, Lys, Thr.</th>
<th>Met, Lys.</th>
<th>Met.</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Protein, %</td>
<td>18.22</td>
<td>18.61</td>
<td>19.01</td>
<td>29.28</td>
</tr>
<tr>
<td>Lysine HCL, lb/ton</td>
<td>1.66</td>
<td>0.67</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DL Methionine, lb/ton</td>
<td>3.26</td>
<td>3.20</td>
<td>3.12</td>
<td>0</td>
</tr>
<tr>
<td>L Threonine, lb/ton</td>
<td>0.33</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cost per ton difference*</td>
<td>-</td>
<td>+ $0.62</td>
<td>+ $1.58</td>
<td>+ $26.28</td>
</tr>
</tbody>
</table>

*$/ton difference from fully supplemented diet

**Source:** Michael Elliot, Wenger Feeds, Rheems, PA
Impact of Dietary Protein Level on Protein Retention and Excreta Nitrogen in Layers

- High dietary protein = high manure nitrogen

<table>
<thead>
<tr>
<th>Dietary Protein Level, %</th>
<th>Protein Retention, %</th>
<th>Excreta Nitrogen, % (Percent Reduction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.9</td>
<td>35.67</td>
<td>6.32</td>
</tr>
<tr>
<td>16.3</td>
<td>38.72</td>
<td>5.88 (7%)</td>
</tr>
<tr>
<td>14.4</td>
<td>39.07</td>
<td>5.12 (19%)</td>
</tr>
</tbody>
</table>

Novak and Scheideler, 2003
Dietary Strategies for Nitrogen

1. Formulate on amino acids (AA) not CP
2. Optimize diet AA with requirement “Ideal Protein”

![Graph showing amino acid requirements](image)
Dietary Strategies for Nitrogen

1. Formulate on AA not CP
2. Optimize dietary AA with requirement
3. Phase-feed for current weight/production

Dietary Crude Protein (%)

[Chart showing dietary crude protein over 6 phases with 3 and 6 phase feeding]
Dietary Strategies for Nitrogen

1. Formulate on amino acids (AA) not CP
2. Optimize dietary AA with requirement “Ideal Protein” concept
3. Phase-feed for current weight/production
4. Select ingredients with low nutrient variability
# Meat Meal Variation

<table>
<thead>
<tr>
<th>Amino Acid %</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Mean</th>
<th>CV %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Met</td>
<td>0.61</td>
<td>0.41</td>
<td>0.49</td>
<td>0.50</td>
<td>20.13</td>
</tr>
<tr>
<td>Cys</td>
<td>0.70</td>
<td>0.30</td>
<td>0.39</td>
<td>0.46</td>
<td>45.62</td>
</tr>
<tr>
<td>Lys</td>
<td>2.77</td>
<td>1.93</td>
<td>1.94</td>
<td>2.21</td>
<td>21.82</td>
</tr>
<tr>
<td>Thr</td>
<td>1.73</td>
<td>1.12</td>
<td>1.25</td>
<td>1.37</td>
<td>23.45</td>
</tr>
<tr>
<td>Arg</td>
<td>3.62</td>
<td>3.00</td>
<td>2.90</td>
<td>3.17</td>
<td>12.3</td>
</tr>
</tbody>
</table>

(Wicker, 1993)
Dietary Strategies for Nitrogen

1. Formulate on amino acids (AA) not CP
2. Optimize dietary AA with requirement “Ideal Protein” concept
3. Phase-feed for current weight/production
4. Select ingredients with low nutr variability
5. Use ingredients “True AA Digestibility”
6. Avoid/control anti-nutritional factors
7. Utilize feed enzymes/additives
Dietary Enzymes for Broilers
(Zanella et al., 1999)

- Ileal AA digestibility
  37d commercial broilers
- Corn/Soy diet ± protease, xylanase, amylase
- CP digest increased 2.9%
- 45d performance trial:
  improved wt gain and F/G
Dietary Phytase for Turkeys
(Yi et al., 1996)

- Corn/Soy ± 750 U/kg BASF phytase
- Ileal amino acid digestibility on 24d turkeys, N dig ↑ 1.3%
- DM & P dig ↑ 3.8 & 7.1%
- 29d performance trial: improved wt gain, F:G and bone ash%

Ileal Digestibility (%)
Hen Ammonia Strategies

Hen Room NH₃ (ppm)/8-day exp periods

Kim and Patterson (2006)
Hen Manure Amendments
Sodium Bisulfate Study

-Manure Total-N sig. increased by PLT1 & 2
-Manure NH4-N sig. increased by PLT1 & 2
Broiler Litter pH

24 days

- Con
- .5S+.75H
- .5S+1.0Z
- .75S+.75H
- .75S+1.0Z
- .75S

42 days

- Con
- .5S+.75H
- .5S+1.0Z
- .75S+.75H
- .75S+1.0Z
- .75S
Broiler Litter Ammonia Flux (mg/m²/min)

![Graph showing broiler litter ammonia flux over 24 and 42 days with different treatments labeled: Con, .5S+.75H, .5S+1.0Z, .75S+.75H, .75S+1.0Z, .75S. The bars are labeled with letters indicating statistical significance groups.]
Hen Manure NH$_3$ Flux Fed Dietary Acids (mg/g manure)
## Hen Manure Analysis (kg/mt)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Tot-N</th>
<th>NH$_3$-N</th>
<th>Org-N</th>
<th>P$_2$O$_5$</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>60.1</td>
<td>8.6</td>
<td>51.5</td>
<td>45.9$^a$</td>
<td>6.85$^b$</td>
</tr>
<tr>
<td>CA 0.30%</td>
<td>52.4</td>
<td>7.1</td>
<td>45.3</td>
<td>42.5$^a$</td>
<td>6.79$^b$</td>
</tr>
<tr>
<td>GA 0.05%</td>
<td>64.7</td>
<td>8.9</td>
<td>55.8</td>
<td>40.0$^{ab}$</td>
<td>7.08$^a$</td>
</tr>
<tr>
<td>PA 0.40%</td>
<td>60.0</td>
<td>7.9</td>
<td>52.1</td>
<td>34.1$^b$</td>
<td>6.93$^{ab}$</td>
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</table>

$P$ value: ![Table with P values](image)

<table>
<thead>
<tr>
<th>36 wk</th>
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<tbody>
<tr>
<td>Total</td>
<td>60.1</td>
<td>8.6</td>
<td>51.5</td>
<td>45.9$^a$</td>
<td>6.85$^b$</td>
</tr>
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<td>34.1$^b$</td>
<td>6.93$^{ab}$</td>
</tr>
</tbody>
</table>

$P$ value: ![Table with P values](image)
Using the Hen as a Bioreactor
Antibody Production to Uric Acid Enzymes

(Kim and Patterson, 2003)
(Adrizal, Patterson, Cravener, 2007)
Transaminase enzymes (aminotransferases) catalyze the reversible transfer of an amino group between two $\alpha$-keto acids.
Materials and Methods

- 2 x 3 factorial: (SA, KA) (CP: 22.5, 19.5, 16.5)
- Cobb Avian 48: males (hatch to 21d)
- 6 replicate cages (8 chicks/cage)
- BW & FI: 7, 14, 21d
## Manure Nitrogen and pH

<table>
<thead>
<tr>
<th>Dietary factors</th>
<th>Solids (%)</th>
<th>Total-N (g/kg manure, DM basis)</th>
<th>NH₄-N (g/kg manure, DM basis)</th>
<th>Organic-N (g/kg manure, DM basis)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14 d</td>
<td>21 d</td>
<td>14 d</td>
<td>21 d</td>
<td>14 d</td>
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<tr>
<td>CP:</td>
<td></td>
<td></td>
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<tr>
<td>22.5</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>52.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>54.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>47.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>47.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.32</td>
<td>2.14</td>
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<td>19.5</td>
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<tr>
<td>52.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>53.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>39.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>39.2&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>16.5</td>
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<td>61.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>63.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>32.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>31.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.83</td>
<td>1.99</td>
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<tr>
<td>AA:</td>
<td></td>
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<td>SA</td>
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<tr>
<td>56.1</td>
<td>54.7</td>
<td>40.9</td>
<td>41.1</td>
<td>2.39&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.39&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>KA</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>55.1</td>
<td>59.1</td>
<td>38.3</td>
<td>38.0</td>
<td>1.91&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.87&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>CP × AA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEM</td>
<td>4.0</td>
<td>4.4</td>
<td>1.7</td>
<td>2.0</td>
<td>0.22</td>
</tr>
<tr>
<td>S. of var.:</td>
<td>*</td>
<td>*</td>
<td>****</td>
<td>****</td>
<td>0.053</td>
</tr>
</tbody>
</table>

### Probabilities

| CP       | *     | *     | ****   | ****   | 0.053 | NS    | ****   | ****   | ***   | NS    |
| AA       | NS    | NS    | 0.08   | 0.06   | *     | **    | NS     | NS     | NS    | *     |
| CP × AA  | NS    | NS    | *      | NS     | 0.06  | 0.06  | NS     | NS     | NS    | NS    |
Summary

- Numerous dietary strategies for reducing fecal nitrogen and ammonia emissions
- Many are cost effective, and improve bird performance
- There are also many management strategies farmers can implement to reduce ammonia emissions
Manure Du Jour

March 18, 2009

Alan Rotz
USDA Agricultural Research Service
Ammonia Emissions from Dairy Farms

Alan Rotz

Pasture Systems and Watershed Management Research Unit
USDA, Agricultural Research Service
University Park, Pennsylvania
Air Quality Concerns

- Ammonia (NH₃)
- Hydrogen sulfide (H₂S)
- Methane (CH₄)
- Nitrous oxide (N₂O)
- Carbon dioxide (CO₂)
- Volatile organic compounds (VOCs)
Where is Ammonia Lost?

- **Barn**: 8-20% of excreted N
- **Storage**: 8-20% of stored N
- **Field Application**: 10-30% of applied N
- **Grazing**: 10% of excreted N
How do We Quantify Losses?

- Measurement
- Modeling
Farm Measurement is Expensive
Wide Variety of Dairy Facilities
Recommended Process-Based Modeling Approach
Farm Simulation Provides a Tool

Integrated Farm System Model

Pasture Systems and Watershed Management Research Unit
USDA / Agricultural Research Service

Integrated Farm System Model
Version 2.0
A tool for evaluating and comparing alternative technologies and management strategies on representative farms.

This program is available to download from the address: http://ars.usda.gov/nea/pawmu.
Model Predictions

- Performance
- Economics
- Environmental impacts
Environmental Impacts

- Volatile N (ammonia) loss
- Denitrification N loss
- Leaching N loss
- Soluble and sediment P runoff losses
- Greenhouse gas emissions
- Whole-farm balances of N, P, K and C
Potential Regulatory Limit

Maximum daily ammonia emission of 100 lb
Maximum Daily Emissions

Confinement farms
- Tie stall barn, daily hauling
- Free stall barn, daily hauling
- Free stall barn, bottom-loaded storage
- Free stall barn, top-loaded storage
- Open drylot

Grazing farms
- Tie stall barn, daily hauling
- Free stall barn, bottom-loaded storage

lb / cow / day

0.0 0.2 0.4 0.6 0.8 1.0

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Maximum Farm Size

Confinement farms
- Tie stall barn, daily hauling
- Free stall barn, daily hauling
- Free stall barn, bottom-loaded storage
- Free stall barn, top-loaded storage
- Open drylot

Grazing farms
- Tie stall barn, daily hauling
- Free stall barn, bottom-loaded storage
A Comparison of Farm Systems

- Tie stall barn, daily haul, surface application
- Free stall barn, slurry tank, surface application
- Free stall barn, slurry tank, injected
- Free stall barn, liquid pond, irrigated
Ammonia Nitrogen Loss

<table>
<thead>
<tr>
<th>Method</th>
<th>Grazing</th>
<th>Field</th>
<th>Storage</th>
<th>Barn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily haul</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tie stall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slurry tank</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Free-stall</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liquid pond</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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Manure Handling Cost

|$/cow$

- Daily haul
- Tie stall
- Slurry tank
- Surface
- Free-stall
- Injected
- Slurry tank
- Liquid pond
- Irrigated
- USDA / ARS
Farm Net Return

<table>
<thead>
<tr>
<th>Method</th>
<th>Surface</th>
<th>Injected</th>
<th>Irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily haul</td>
<td>500</td>
<td>500</td>
<td>600</td>
</tr>
<tr>
<td>Tie stall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slurry tank</td>
<td>500</td>
<td>500</td>
<td>600</td>
</tr>
<tr>
<td>Free-stall</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

USDA / ARS
What more can be done to reduce ammonia loss?
Applied to Our Farms

- Use of these N conservation technologies on Pennsylvania dairy farms can reduce ammonia emissions by 55 - 75%.
- The cost of this technology exceeds the value of the N saved, causing a reduction in annual net return of about $80/cow.
Ammonia emissions from livestock facilities can be substantial.

A limit of 100 lb/day can be exceeded on many of our dairy farms on a warm summer day.

Whole farm simulation provides a useful tool for evaluating the environmental and economic trade-offs of alternative production systems.
Model Availability

http://ars.usda.gov/naa/pswmru
Pasture Systems and Watershed Management Research Unit

University Park, Pennsylvania
Question and Answers

• Questions received in writing will be directed to the speakers by the host.
• Questions not answered during the time remaining, will be posted with answers at www.aec.cas.psu.edu
• Recordings of this session can also be viewed at the URL listed above.
Next Week on Manure Du Jour: Air Quality
NUTRITION AND GREENHOUSE GAS EMISSIONS

• Returning:
  – Dr. Alex Hristov, PSU Department of Dairy and Animal Sciences
  – Dr. Alan Rotz, USDA Agriculture Research Service

• Joining Dr. Hristov & Dr. Rotz:
  – Dr. Wendy Powers, Michigan State University, Animal Science and Ag and Biosystems Engineering

For more information
Penn State Ag & Environment Center
www.aec.cas.psu.edu