Feeding Tannins to Dairy Cows
Abates Ammonia Emissions from Barns and Soils

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Outline

- **Background**: Sources and Impacts of ammonia emission; ammonia formation and emission.

- **Cow Trial**: Effect of dietary crude protein (CP) and tannin extracts on animal performance and Fecal vs. Urinary nitrogen partitioning.

- **Lab/Field Scale Trials**: Effect of dietary CP and tannin extracts on NH$_3$ emission from simulated dairy barns floors (trial 1 to 3) and soil (trial 4).

- **Overall Conclusions**
Sources and Impacts of Ammonia Emission

- Manure from livestock operations (i.e., farms) is the major source (~50%) of anthropogenic NH₃ emission in the United States
  - Dairy cattle manure comprises ~24% of all livestock emissions (EPA, 2005).

- Ammonia emission affects atmospheric visibility, terrestrial and aquatic ecosystems and human health.

- Ammonia losses from animal manure during collection, storage and field application reduce its value as a fertilizer for crops.
Ammonia Formation and Emission

Feces N + Urease → NH₄⁺ sol

Urine N (urea) + Temperature and pH → NH₄⁺ sol

NH₄⁺ sol → NH₃ sol

NH₃ sol → NH₃ gas

NH₃ gas → Resistance → Emitting surface → Concentration gradient

Temperature, pH and solution ions
Outline

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Background

Tannins are naturally occurring plant polyphenols with multiple phenolic hydroxyl groups, may form complexes with proteins, metal ions, amino acids and polysaccharides.

They are broadly classified into hydrolysable (HT) and condensed tannins (CT).

Previous research indicated that responses to HT and CT depend on their dietary concentration and diet composition.
Material and Methods

- Twenty-four (8 ruminally cannulated) multiparous lactating cows.

- Main Plot was set up as a complete randomized design (CRD) with the following treatments:
  - 15.5 and 16.8 % CP of diet DM.

- Sub-plot was set up as a 4x4 Latin square design
  - rice hulls were replaced with a tannin extracts mix from quebracho and chestnut tree (2:1 ratio) in stepwise increments (0, 0.45, 0.90 and 1.80% of dietary DM).

- Total fecal and urine collection of cannulated cows.
### Results: Performance and Manure N

<table>
<thead>
<tr>
<th>Tannin extract (% DM)</th>
<th>P-value(^1)</th>
<th>Diet CP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>L 0.08</td>
<td>15.5</td>
</tr>
<tr>
<td>0.45</td>
<td>Q 0.25</td>
<td>16.8</td>
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<tr>
<td>0.90</td>
<td></td>
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<td>1.80</td>
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<tr>
<td>DMI kg/d</td>
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<td></td>
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<tr>
<td>Milk, kg/d</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>N intake, g/d</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Manure N, g/d</td>
<td></td>
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\(^1\)L = Linear effect; Q = Quadratic effect.
## Results: N Partitioning

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</tr>
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<td>15.5</td>
<td>16.8</td>
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</table>

<table>
<thead>
<tr>
<th>Fecal N, g/d</th>
<th>214$^b$</th>
<th>234$^a$</th>
<th>245$^a$</th>
<th>250$^a$</th>
<th>$&lt;0.01$</th>
<th>0.06</th>
<th>257</th>
<th>214</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Urine-urea N, g/d</th>
<th>141$^a$</th>
<th>134$^a$</th>
<th>136$^a$</th>
<th>115$^b$</th>
<th>$&lt;0.01$</th>
<th>0.22</th>
<th>99$^B$</th>
<th>164$^A$</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Urine N, g/d</th>
<th>213$^a$</th>
<th>201$^a$</th>
<th>207$^a$</th>
<th>177$^b$</th>
<th>$&lt;0.01$</th>
<th>0.24</th>
<th>167$^B$</th>
<th>232$^A$</th>
</tr>
</thead>
</table>

$^1$L = Linear effect; Q = Quadratic effect.

$^{a,b}$Least squares means within the same row with different superscripts differ ($P < 0.05$).
Cow Trial Conclusions

- Reducing dietary CP from 16.8 to 15.5 % had a profound impact on urinary N excretion, mostly in the form of reduced urea-N excretion, but had no effect on milk production.

- Results suggested that feeding tannin extracts up to 0.90% of the diet dry matter had minor effects on animal performance.

- Incorporating tannins in the diet did not alter total manure N excretion but altered the proportion excreted in the urine (more vulnerable to environmental loss) and feces (more resilient to environmental loss).
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- **Lab/Field Scale Trials**: Effect of dietary CP and tannin extracts on NH₃ emission from dairy barns floors (trial 1 to 3) and soil (trial 4).
- Overall Conclusions
Objectives

- Determine the effect on NH$_3$ emission of:
  - Trial 1: Feces-urine mixture from cows fed four levels of tannin extracts at two CP levels applied to simulated barn floors
  - Trial 2: Feeding tannins extracts on urease activity in feces
    - urea solution was added to feces obtained from cows fed 0 (Control), 0.45 and 1.80% tannin extract at 16.8% CP
  - Trial 3: Tannin extracts application directly to simulated barn floor
    - tannin extract amounts equivalent to those fed at 0 (Control), 0.45 and 1.80%
  - Trial 4: Feces-urine mixture from cows fed four levels of tannin extracts at two CP levels applied to a sandy loam and a silt loam soil
Material and Methods

Ammonia emissions from manure surface

Inlet acid trap

Emissions chamber

Outlet acid trap

Flow meter

Pump
Feces and urine applied to mini-chambers in Trials 1 and 4

<table>
<thead>
<tr>
<th>Dietary CP (% of diet dry matter)</th>
<th>Tannin (%)</th>
<th>Feces to urine ratio</th>
<th>Total N applied (mg)</th>
</tr>
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<tbody>
<tr>
<td>15.5</td>
<td>0</td>
<td>2.01</td>
<td>75</td>
</tr>
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<td>70</td>
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<td>0.90</td>
<td>2.26</td>
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<td></td>
<td>1.80</td>
<td>2.41</td>
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<tr>
<td>16.8</td>
<td>0</td>
<td>1.64</td>
<td>95</td>
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<td>1.70</td>
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</tr>
<tr>
<td></td>
<td>1.80</td>
<td>2.13</td>
<td>86</td>
</tr>
</tbody>
</table>
Effect of Tannin and CP Level on NH$_3$-N Emission

- Control
- 0.45% Tannin
- 0.90% Tannin
- 1.80% Tannin

Cumulative NH$_3$-N emission (mg)

Hours after manure application

16.8% CP

16% reduction

15.5% CP

32% reduction

*** ' and '***' above data points refer to significant differences of \( P<0.05 \) and \( P<0.001 \), respectively.

-Cumulative NH$_3$- N at 48 h with different letters differ significantly (\( P<0.001 \)).
Effect of Fecal Tannins on NH$_3$-N Emission (Trial 2)

Cumulative NH$_3$-N emission (mg) vs. Hours after manure application.

- Control
- 0.90% Tannin
- 1.80% Tannin

11.5% reduction
Effect of Direct Application of Tannin on NH$_3$-N emission (Trial 3)

Cumulative NH$_3$-N emission (mg)

Hours after manure application

- Control
- MTE$_x$
- HTE$_x$

20% reduction

***

*
Effect of Dietary CP on NH$_3$-N Emission from Soils (Trial 4)

54% reduction
Effect of Tannin Extracts on NH$_3$-N Emission from Soils (Trial 4)

Cumulative NH$_3$-N emission (mg)

Hours after manure application

- Control
- 0.45% Tannin
- 0.90% Tannin
- 1.80% Tannin

27% reduction
Lab/Field Scale Trial Conclusions

- Level of dietary CP had greatest overall impact on cumulative-48hr emissions.

- Both when incorporated in the diet and when directly applied to barn floor, tannin extract reduced cumulative-48hr NH$_3$ emissions from simulated barn floors and after application to soil.
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Overall Conclusions

- The effectiveness of tannin extract in reducing cumulative-48hr \(\text{NH}_3\) emissions could be attributed to two factors:
  - Change in N partitioning (fecal vs. urine)
  - Reductions in urease activity in feces

- Larger scale and longer term field trials are needed to ascertain effectiveness of tannin extracts in abating \(\text{NH}_3\) emission from barn floor and land-applied manure.
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