Increasing the utilisation of forage protein in ruminant diets

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N-use efficiency

- Milk N as a % of Feed-N (n=51 expts)
  - Mean: 27.6
  - Range: 14.5 to 40.0
  - Particular problem with forages
Synchrony of nitrogen and energy supply in the rumen

Plant Proteins (Fast)

Energy (Slow)

Urea

NH₃

Urine

Time
Evidence for synchrony effect?

- Difficult to separate synchrony and specific raw material effects?
- Contradictory results: one study showed higher microbial efficiency with an asynchronous diet
- Better to consider the balance of substrates
Two Basic Approaches

• Increase fermentable energy supply
  – High-sugar grasses
  – Forage mixtures (maize silage)

• Reduce rate of protein degradation
  – Polyphenol oxidase (red clover)
  – Plant proteolysis
Complementary science

• High-sugar grasses
  – cold tolerance

• Polyphenol oxidase
  – plant defence (pathogen/pest)

• Plant proteolysis
  – senescence
Two Basic Approaches

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Seasonal Change in WSC Content

The graph shows the seasonal change in WSC (Water-Soluble Carbohydrates) content from March to August 1998. Two lines represent different conditions: a 'High' line and a 'Control' line. The graph indicates fluctuations in WSC content over time, with notable peaks and troughs corresponding to specific dates. The x-axis represents dates from 04-Mar-98 to 31-Aug-98, while the y-axis shows the %WSC content.
High sugar grasses
Efficiency of microbial protein synthesis

In Vitro

Level of sugar supply

<table>
<thead>
<tr>
<th></th>
<th>Microbial N (g/Kg OMAD)</th>
<th>WSC in vessel (g/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basal</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>x1.2</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>x1.5</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>x1.8</td>
<td>15</td>
<td>12</td>
</tr>
</tbody>
</table>

NS: Not Significant
P< 0.001
N partitioning in dairy cows grazing control and high sugar grass (HS)

Miller et al. 2002
Two Basic Approaches

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Previous work on forage legumes

+ Yield 10-12 tonnes of DM per ha with no N fertiliser (sustainable systems)
+ Higher voluntary intakes
+ Higher milk production
+ Increased PUFA in milk

- Low N-utilisation
N-use efficiency

- N intake effect
- Concentrate effect
- Forage effect (white clover)

Dewhurst et al. 2003
White clover silage

- Higher rumen fermentation rate than grass silage
- Higher rumen passage rate than grass silage

**HOWEVER, little evidence of increased N-use efficiency in the rumen**

- Effect appears related to increased energy supply to animal tissues (high DM intake and digestibility)
### DM intake of legume silages

<table>
<thead>
<tr>
<th>Silage Type</th>
<th>Silage DM Intake (kg/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>11.5</td>
</tr>
<tr>
<td>50% Red clover</td>
<td>13.0</td>
</tr>
<tr>
<td>100% Red clover</td>
<td>14.0</td>
</tr>
<tr>
<td>50% White clover</td>
<td>12.5</td>
</tr>
<tr>
<td>100% White clover</td>
<td>12.0</td>
</tr>
<tr>
<td>Lucerne</td>
<td>16.0</td>
</tr>
</tbody>
</table>

SED = 0.80; P < 0.001

*Source: Dewhurst et al. 2003*
Digestibility of legume silage-based diets

Diet digestibility (%)

Grass 70
50% Red clover 65
100% Red clover 60
50% White clover 75
100% White clover 65
Lucerne 50

SED=0.96; P<0.001

Dewhurst et al. 2003
Maize silage to complement white clover silage

• Grass silage (GS)
• 0.6 grass silage + 0.4 maize silage (60GS/40MS)
• 0.2 white clover silage + 0.8 maize silage (20WCS/80MS)
• 0.4 white clover silage + 0.6 maize silage (40WCS/60MS)
DM intake (kg/day)

SED=0.54; P<0.001

Dewhurst et al., 2004
Milk yield (kg/day)

SED = 0.71; P < 0.05

G S  60GS/40MS  20WCS/80MS  40WCS/60MS

Dewhurst et al., 2004
Milk protein (g/kg)

SED=0.52; P<0.01

Dewhurst et al., 2004
Milk and Urine N output (g/day)

41% less urine N per unit milk N

Dewhurst et al., 2004
Two Basic Approaches

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  - **Polyphenol oxidase (red clover)**
  - Plant proteolysis
What is Polyphenol oxidase?

- Enzyme
- Oxidises phenols to quinones
- Quinones are very reactive and “sticky”
- Cause complexing of proteins
- Protein complexes are difficult to break down
Polyphenol oxidase in red clover

Normal Red Clover  Low PPO Red Clover
Protein Breakdown in Red Clover Leaf Extracts

Protein Breakdown (%)

Time (hours)

Low PPO

High PPO
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Plant proteolysis

- Increased temperature
- Oxygen deficiency
- Products of microbial metabolism
- Invasion by rumen microorganisms
- Mechanical damage
- Dark

Degradation

Protein turnover

Synthesis
In vitro proteolysis
Protein degradation \textit{in vitro}

The diagram shows the leaf protein content (mg g\textsuperscript{-1} FWT) over time (h) at different temperatures and oxygen conditions. The x-axis represents the incubation time in hours (0, 1, 2, 6, 12, 24), and the y-axis represents the leaf protein content. The blue bars indicate 25\degree C + O\textsubscript{2}, while the red bars represent 39\degree C - O\textsubscript{2}. The error bars indicate the variability in the data.
Half-life of leaf protein

![Graph showing half-life of leaf protein for different plants.](image-url)
Lolium vs Festuca

Protein (% of original) vs Incubation time (h)

Festuca arundinacea
Lolium perenne
Conclusions

• Potential to increase utilisation of forage N by:
  – increasing levels of sugar and starch (e.g. high-sugar grasses; maize silage)
  – using high-intake forages and forage mixtures
  – selecting species and traits with lower rates of protein degradation