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Ruminant Enzymes: The Future of Dairy Cow Nutrition?

Dr Nicola Walker

Nicola did her PhD at the Rowett Research Institute in Aberdeen, Scotland on microbes involved in excessive rumen protein and peptide breakdown with Dr John Wallace and Dr Jamie Newbold. She then continued at the Rowett studying microbes involved in rumen biohydrogenation, and the use of feed additives to manipulate rumen fermentation and microflora. Nicola moved to New Zealand in 2002 to work as a research scientist on different strategies to reduce methane emissions from grazing ruminants at AgResearch, Palmerston North. There she tested the effect of different plants and plant extracts on altering fermentation and the rumen flora and isolating bacteriophage which killed methanogens.

After 3 years in NZ she then went to work for Lallemand Animal Nutrition as R&D manager. Based at INRA, Clermont Ferrand for the first 3 years and then heading up the R&D lab in Montreal for Lallemand Animal Nutrition North America for a further 3 years. Whilst at Lallemand, she screened a large number of yeast strains for different effects on rumen fermentation and the rumen microflora, and developed an understanding of the mode of action of live yeast and the benefits they can bring to improve rumen health and productivity.

Nicola returned to the UK in 2010 to work for AB Vista as Ruminant Product Development Manager where she has been for the last 3 years, developing yeast, yeast derivatives, fibrolytic enzymes and other additives for ruminant feeds. Her role there is both in R&D and developing new products, and providing Technical Support for AB Vista's distributors and customers involved in the ruminant feed industry world-wide. Nicola has been an author on 27 published papers in peer reviewed journals and 1 book chapter in the areas of rumen microbiology and the effects of feed additives on rumen fermentation and the rumen flora.
Feed Enzymes: The Future of Dairy Cow Nutrition?

Dr Nicola Walker, AB Vista

Large Herd Seminar

Enzyme – lock and key mechanism

Enzymes are proteins, with tertiary or quaternary structures. Biological catalysts, with specific reactions vs substrate. Activity affected by:
- environmental factors (temp and pH)
- co-factors and coenzymes
- enzyme inhibitors

Enzyme –锁和钥匙机制

酶是蛋白质，具有三级或四级结构。生物催化剂，对底物有特定的反应。活性受到的影响有：
- 环境因素（温度和pH）
- 辅酶和辅酶
- 酶抑制剂

Enzymes, used every day

Textile
Baking
Specialties
Feed
Pulp and Paper

Wide range of industrial applications.
Examples - Amylases, Proteases, Cellulases, Xylanases, Glucanases, Pectinases, Phytases, Lipases, Mannanases, Galactosidases……

Feed enzymes in monogastric systems

Used since late 1980s
Well established, extensive supporting research
Use driven by:
- improved feed digestibility and efficiency
- removal anti-nutritive effects
- reduce environmental effects

Main types of enzymes used:
1. Carbohydrases
   - Xylanases
   - Glucanases
   - Mannanases
   - Amylases
2. Phytases
3. Proteases

Benefits of feed enzymes in monogastrics

Unlike ruminants, monogastrics do not benefit from the ability of the gastro-intestinal microbes to degrade, for example, phytate and fibre until the lower gut.

This can result in poor digestibility, leading to lost performance and increased excretion.

Enzymes are normally given a nutrient value in least cost formulations, resulting in feed cost savings

Rarely used as “over the top” feed additives

Benefits of feed enzymes in monogastrics

<table>
<thead>
<tr>
<th>Enzyme</th>
<th>Use</th>
<th>Benefit to producer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phytase</td>
<td>Destruction of phytate</td>
<td>Reduced feed costs, lower P excretion</td>
</tr>
<tr>
<td>Xylanase &amp; β-Glucanase</td>
<td>Breakdown of plant fibre, reduction in digesta viscosity</td>
<td>Lower feed costs, improved feed efficiency, better litter quality</td>
</tr>
<tr>
<td>Amylase</td>
<td>Breakdown of starch</td>
<td>Better feed efficiency</td>
</tr>
<tr>
<td>Protease</td>
<td>Breakdown of protein</td>
<td>Better feed efficiency</td>
</tr>
</tbody>
</table>
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Evolution of feed enzymes market

Enzymes in ruminant feed - Past

- Primarily on Xylanases & Cellulases, to improve forage fibre digestibility
- Variable results due to:
  - different enzyme compositions
  - different dose rates
  - dietary interactions
- Production costs prohibitive to make commercial use a viable proposition
- However..........................

Fibre degrading microorganisms – Anaerobic fungi

Initial colonisers of fibre particle
- Weaken plant cell wall
- Cellulolytic and hemicellulolytic enzyme activities
- 8% rumen microbial population
- Numbers and role sometimes underestimated and overlooked
- Affected by pH

Ruminant feed enzymes – what’s changed?

- Enzyme production costs have significantly decreased.
- Milk prices have increased.
- Feed prices have increased.
- Requirement to improve feed utilisation and feed efficiency – sustainable agriculture.
- Increased interest in improving forage utilisation
- We have a better understanding of the science and mode of action.

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Feed enzymes for ruminants
Protozoa account for up to 33% fibre degradation in the rumen. Hemicellulolytic activity If removed by defaunation, fibre digestion is reduced. The fibre-digesting protozoa are sensitive to drops in rumen pH caused by high levels of concentrate.

Cellulolytic and hemicellulolytic 3 major cellulolytic bacteria – F. succinogenes, R. albus and R. flavefaciens Range of hemicellulolytic bacteria e.g. Prevotella, Butyrivibrio Activity and growth affected by pH

Plant fibre breakdown by the main fibrolytic bacteria

Effect of fibrolytic enzymes on feed surface

Application of enzymes to the forage causes pits to form in the surface of the fibre

Effect of fibrolytic enzymes on feed surface colonisation by microbes

Feed enzymes cause faster colonisation of the fibre

Effect of fibrolytic enzymes on lag time to digestion and feed digestibility

Increased predicted ME, reduced lag time to digestion, increased % fermentable NDF
Fibrolytic enzymes affected the microbial populations

Early lactation animals fed feed + enzyme had significantly higher levels of Fibrolytic bacteria
Hemicellulolytic bacteria were numerically increased
There was an interaction between fibrolytics and Selenomonads

Effect of fibrolytic feed enzymes on performance

<table>
<thead>
<tr>
<th>5-30th wks of lactation</th>
<th>Control</th>
<th>TMR treated</th>
<th>Conc treated</th>
<th>Rumen infused</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 cows (4x4 latin square), TMR based on corn silage (42% DM), grass silage (14% DM) &amp; concentrate (43% DM)</td>
<td>Sutton et al, J. Dairy Sci., 2003</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total tract DM dig. (%)</td>
<td>71.4ab</td>
<td>72.4b</td>
<td>70.7a</td>
<td>71.4ab</td>
</tr>
<tr>
<td>Duodenal N flow (g/d)</td>
<td>656</td>
<td>710</td>
<td>731</td>
<td>656</td>
</tr>
<tr>
<td>Duodenal viscosity (cP)</td>
<td>3.1</td>
<td>2.9</td>
<td>3.4</td>
<td>3.3</td>
</tr>
<tr>
<td>Postrumen NDF dig. (%)</td>
<td>9.0ab</td>
<td>24.7e</td>
<td>16.1ab</td>
<td>6.8a</td>
</tr>
<tr>
<td>Fecal starch (g/d)</td>
<td>190a</td>
<td>150b</td>
<td>190a</td>
<td>170ab</td>
</tr>
<tr>
<td>Stover retention time (hr)</td>
<td>36.2</td>
<td>58.3</td>
<td>54.5</td>
<td>55.7</td>
</tr>
<tr>
<td>Milk yield (kg/d)</td>
<td>34.0</td>
<td>35.5</td>
<td>34.5</td>
<td>35.0</td>
</tr>
<tr>
<td>Protein yield (kg/d)</td>
<td>1.14a</td>
<td>1.18b</td>
<td>1.19b</td>
<td>1.17ab</td>
</tr>
</tbody>
</table>

*P<0.05

Feed enzyme Dairy Trial (Holtshausen et al. 2011)

Enzyme treatment:
- Reduced Dry Matter Intake
- No impact on Milk Yield
- Improved Feed Efficiency with increasing Enzyme
- Improved % Protein in Milk
- Numerically improved Weight Gain
  - Indication of less mobilisation of own reserves
  - Potentially beneficial reproduction functionality

Meta-analysis of supplementing dairy diets with exogenous fibrolytic enzyme products (Eun et al 2011)

<table>
<thead>
<tr>
<th></th>
<th>Enzyme</th>
<th>SE</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI (kg/d)</td>
<td>23.1</td>
<td>23.3a</td>
<td>0.22</td>
</tr>
<tr>
<td>Milk yield (kg/d)</td>
<td>34.8</td>
<td>37.1**</td>
<td>0.03</td>
</tr>
<tr>
<td>ECM yield (kg/d)</td>
<td>36.4</td>
<td>38.1*</td>
<td>0.49</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>3.73</td>
<td>3.64</td>
<td>0.074</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>3.18</td>
<td>3.17</td>
<td>0.034</td>
</tr>
<tr>
<td>Milk fat (kg/d)</td>
<td>1.29</td>
<td>1.35</td>
<td>0.038</td>
</tr>
<tr>
<td>Milk protein (kg/d)</td>
<td>1.10</td>
<td>1.16*</td>
<td>0.02</td>
</tr>
<tr>
<td>Milk production efficiency</td>
<td>1.52</td>
<td>1.59**</td>
<td>0.022</td>
</tr>
<tr>
<td>ECM-DMI</td>
<td>1.60</td>
<td>1.63</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Significant increase in milk yield (+2.3 litres), DMI, milk protein and feed efficiency (P<0.05)
Effect of exogenous fibrolytic ruminant enzymes

- Colonisation
- Cellulolytic bacteria
- Lag time to digestion
- Feed utilisation & efficiency
- Predicted ME of the feed

Enzyme added to feed, causes pits to form on the surface of the fibre

= increase in milk yield and feed efficiency

Feed enzymes: the use for dairy nutrition is bright!!!!

Questions???????????