Innovative and practical management approaches to reduce nitrogen excretion by ruminants

Response of Dairy Cows to Supplements of Energy and Protein in Early and Mid Lactation

Ryan Law, Fiona Young and Conrad Ferris
Agri-Food & Biosciences Institute (AFBI)

- AFBI was established on 1 April 2006
- 800 staff on 7 specialised sites across Northern Ireland

Newforge Lane, Belfast
Stormont
Omagh
Crossnacreevy
Loughgall
Hillsborough
Bushmills
AFBI Hillsborough

- Formerly the Agricultural Research Institute of Northern Ireland (ARINI) - established in 1926

- Became part of AFBI at its formation

- Research into sustainable livestock systems (dairy, beef, sheep, pigs) & Renewable energy
Dairy Research at AFBI Hillsborough

- 320 dairy cows
- 140 high genetic merit (HGM) Holstein Friesians
- 9,750 litres per 305 day lactation
Overview of Presentation (2 Parts)

1. To examine the response of lactating dairy cows to dietary protein content, and examine if protein can be used as a tool to modify energy balance

2. To examine some of the factors influencing the response of lactating dairy cows to supplementary energy

- Data presented is from research conducted at AFBI Hillsborough (mostly during last 10 years)
Phosphorus is main water quality issue in NI - eutrophication

Waters in NI have good quality in respect to Nitrates

Nevertheless, research targeted at reducing nitrogen excretion from livestock

N intake is a key driver of N excretion

\[ R^2 = 0.89 \]
Background (II) - Reducing Cost of Milk Production

- Concentrates represent 60-70% of variable costs of milk production in NI
- Concentrate prices look set to increase in the future
- Need to optimise concentrate use in dairy cow diets

Huge variation in response to concentrate use on farm
Background (III) - Meeting Nutrient Requirements of High Yielding Cows

- Genetic merit of UK dairy cows has increased dramatically during the last 2 decades
- High yielding cows can not eat enough in early lactation to support milk production

Negative energy balance:
- Reduced immunity
- Increased risk of metabolic disorders (ketosis, fatty liver syndrome)
- Poor fertility
Part 1 - Response of Dairy Cows to Dietary Protein and the Potential of Protein Nutrition to Change Energy Balance

Points to be covered:

- Response to dietary protein: low/moderate yielding cows vs. high yielding cows
  - early lactation
  - mid/late lactation
- Using protein to change energy balance of cows
- Role of protected methionine
Response of Low-Moderate Yielding Cows to Level of Protein in Diet

- Interest in dietary protein is not new (research at Hillsborough since 1970’s)
- However, historically emphasis was to increase milk production by feeding higher protein diets
- Protein was recognised as an important driver of intake
Response of Low-Moderate Yielding Cows to Level of Protein in Diet

- A curvilinear relationship was established between milk yield and the protein content of the supplement (Gordon & McMurray, 1979)
Relationship between Concentrate Feed Level and Level of Protein in the Concentrate (100, 220, 340 & 460 g CP / kg concentrate)
Response of High Yielding Cows to Level of Protein in Diet

- Recent AFBI research
- 3 levels of protein in diet: 11.5 % DM, 14.5 % DM, 17.5 % DM
- Concentrate inclusion level = 55% DM
- On study from calving till day 150 of lactation
**Effect of Dietary Protein Content on Cow Performance (First 150 Days of Lactation)**

<table>
<thead>
<tr>
<th>Crude protein content of diet (% DM)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.5</td>
<td></td>
</tr>
<tr>
<td>14.5</td>
<td></td>
</tr>
<tr>
<td>17.5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dry matter intake (kg/d)</th>
<th>16.5</th>
<th>18.0</th>
<th>18.6</th>
<th>***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield (kg/d)</td>
<td>25.4</td>
<td>31.8</td>
<td>35.4</td>
<td>***</td>
</tr>
<tr>
<td>Milk composition (g/kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>42.0</td>
<td>38.3</td>
<td>38.1</td>
<td>***</td>
</tr>
<tr>
<td>Protein</td>
<td>31.4</td>
<td>32.3</td>
<td>32.4</td>
<td>NS</td>
</tr>
<tr>
<td>Fat + protein yield (kg/d)</td>
<td>2.15</td>
<td>2.41</td>
<td>2.70</td>
<td>***</td>
</tr>
</tbody>
</table>
Effect of Dietary Protein Content on Daily Energy Balance (MJ / day)

Daily energy balance (MJ/day)

Week of lactation

-70 -50 -30 -10 10 30 50

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

11.5% 14.5% 17.5%
### Effect of Dietary Protein Content on Reproductive Performance (30 Cows / Treatment)

<table>
<thead>
<tr>
<th>Crude protein content of diet (% DM)</th>
<th>11.5</th>
<th>14.5</th>
<th>17.5</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pregnancy to first service (%)</td>
<td>34.5</td>
<td>29.7</td>
<td>27.6</td>
<td>NS</td>
</tr>
<tr>
<td>100 day in-calf rate (%)</td>
<td>82.7</td>
<td>66.7</td>
<td>62.1</td>
<td>NS</td>
</tr>
<tr>
<td>Conception rate (%)</td>
<td>100.0</td>
<td>92.9</td>
<td>86.7</td>
<td>NS</td>
</tr>
<tr>
<td>Calving Interval (days)</td>
<td>398</td>
<td>399</td>
<td>398</td>
<td>NS</td>
</tr>
</tbody>
</table>
Effect of Dietary Protein Content on the Efficiency of Nitrogen Utilisation and Methane Production

<table>
<thead>
<tr>
<th>Crude protein content of diet (% DM)</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11.5</td>
</tr>
</tbody>
</table>

| N intake (g / cow / day)   | 322  | 445  | 562  | *** |
| N in milk (g / cow / day)  | 100  | 132  | 144  | *** |
| N in manure (g / cow / day)| 227  | 300  | 380  | *** |
| N balance (g / cow / day)  | -5   | 13   | 38   | *** |
| Milk N / N intake (g / g)  | 0.310| 0.297| 0.256| *** |
| CH4 / milk yield (l / kg)  | 25.7 | 20.9 | 20.4 | **  |
| CH4 / DM intake (l / kg)   | 31.1 | 28.2 | 28.2 | *   |
Effect of Lowering the Dietary Protein Content at Day 151 of Lactation on Milk Production

Half of the cows moved onto a medium protein diet at day 151 post calving. Protein levels can be reduced at day 151 of lactation without being detrimental to milk yield.

Protein levels can be reduced at day 151 of lactation without being detrimental to milk yield.
Can Dietary Protein be Used as a Tool to Manage the Energy Status of Individual Cows?

- Severe negative energy balance is associated with poor fertility
- Reducing dietary protein levels ‘switches off’ milk production, improves energy status, and this could improve fertility
- Can dietary protein be reduced for short periods of time without being detrimental to production?

- Two treatments were examined:
  - Control
  - Individual cow management
**Individual Cow Management Treatment**

- Dietary protein levels used to adjust energy balance of individual animals to target energy balance trajectory.

![Graph showing energy balance trajectory](chart.png)

- **Above target** - Increase protein level to 20% CP.
- **Below target** - Decrease protein level to 15% CP.
- **On target** - Maintain at 17% CP.
Milk Yield (kg / day)

P > 0.05

Week of lactation

Milk yield (kgs/day)

Control
Ind. Cow
Daily Energy Balance (MJ / day)

*** P<0.001 ***

Week of lactation

Daily energy balance (MJ)

Control vs. Ind. Cow
Summary of the Effects of Managing Individual Cows to Achieve a Target Energy Balance, on Cow Performance and Fertility (25 Cows / Treatment)

<table>
<thead>
<tr>
<th>Day 1 – 210 of lactation</th>
<th>Control</th>
<th>Individual cow</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total DM intake (kg/day)</td>
<td>19.7</td>
<td>21.0</td>
<td>***</td>
</tr>
<tr>
<td>Milk yield (kg/day)</td>
<td>32.8</td>
<td>32.7</td>
<td>NS</td>
</tr>
<tr>
<td>Energy balance (MJ / day)</td>
<td>18.4</td>
<td>31.7</td>
<td>***</td>
</tr>
<tr>
<td>100 day in-calf rate (%)</td>
<td>71.4</td>
<td>79.2</td>
<td>NS</td>
</tr>
<tr>
<td>Overall pregnancy rate (%)</td>
<td>85.7</td>
<td>95.8</td>
<td>NS</td>
</tr>
</tbody>
</table>

Individual cow management strategy improved energy status, but had no significant effect on fertility
Can Low Protein Diets be Supplemented with Methionine to Maintain Animal Performance?

- Previous work highlights loss in performance at lower levels of protein (144 g CP / kg DM)
- Decline in performance not due to overall deficit in dietary protein but shortage of one or two specific amino acids
- Lysine and methionine
- The majority of UK diets supply sufficient quantities of lysine but insufficient quantities of methionine
Effect of Supplementing a Low Protein Diet with Protected Methionine

- To address this issue, an experiment was conducted using two diets:
  - Control (180 g CP/kg DM)
  - Low protein + protected methionine (150 g CP/kg DM + 40 g methionine)
  - Optimum ratio of lysine:methionine = 3:1
Dry Matter Intake (kg / day)

- Control
- Low Protein

P > 0.05
Milk Yield (kg / day)

P > 0.05
Part 2 - Response of Dairy Cows to Concentrate Supplementation (Recent AFBI Studies)

Points to be covered:

- Concentrates during the transition period
- Concentrate build up strategies in early lactation
- Factors affecting response to concentrates
  - Stage of lactation
  - Silage Quality
  - Genotypes
- Methods of offering concentrates
Concentrate Feeding During the Transition Period

- Still much uncertainty about optimum ‘Energy Nutrition’ during the transition period

- A number of transition cow management strategies exist, including restricting energy intake

- Reduced energy intake during the dry period increased blood NEFA’s pre partum but lowered liver lipid contents post partum (Douglas et al., 1998)

- Increased plasma NEFA concentrations during the dry period prime the liver to better deal with increased NEFA concentrations post partum (Friggens et al., 2004)

- Body reserve mobilisation during the dry period reduced body tissue mobilisation at the start of lactation (Grum et al., 1996)
Relationships between Energy Intake Pre-calving, & Post-calving Performance

- 2x2 factorial design

Pre-calving
  - High energy intake (36% conc., ad lib.)
  - Low energy intake (17% conc., restricted)

Post-calving
  - High energy diet (70% conc.)
  - Low energy diet (30% conc.)

- Animals on diets for first 250 d of lactation
### Effect of Pre-calving Energy Intake on Pre-calving Performance (day -21 to Calving)

<table>
<thead>
<tr>
<th></th>
<th>Ad libitum</th>
<th>Restricted</th>
<th>SED</th>
<th>Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME intake (MJ/d)</td>
<td>95.2</td>
<td>68.0</td>
<td>3.32</td>
<td>***</td>
</tr>
<tr>
<td>Body condition at calving</td>
<td>2.74</td>
<td>2.49</td>
<td>0.06</td>
<td>***</td>
</tr>
<tr>
<td>Daily energy balance (MJ/d)</td>
<td>-19.8</td>
<td>-40.8</td>
<td>4.49</td>
<td>***</td>
</tr>
<tr>
<td>Plasma NEFA (meq/l)</td>
<td>0.38</td>
<td>0.41</td>
<td>0.05</td>
<td>NS</td>
</tr>
</tbody>
</table>
## Treatment Effects on Intake and Milk Production Parameters (Calving to Day 100 Post-calving)

<table>
<thead>
<tr>
<th>Pre-calving treatment</th>
<th>Ad lib.</th>
<th>Restricted</th>
<th>SED</th>
<th>Pre</th>
<th>Post</th>
<th>Int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-calving treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter intake (kg/d)</td>
<td>17.6</td>
<td>14.7</td>
<td>18.5</td>
<td>14.4</td>
<td>0.41</td>
<td>NS</td>
</tr>
<tr>
<td>Milk yield (kg/d)</td>
<td>32.7</td>
<td>28.1</td>
<td>32.2</td>
<td>28.3</td>
<td>1.33</td>
<td>NS</td>
</tr>
<tr>
<td>Milk F + P yield (kg/d)</td>
<td>2.27</td>
<td>2.06</td>
<td>2.20</td>
<td>2.09</td>
<td>0.07</td>
<td>NS</td>
</tr>
</tbody>
</table>
Treatment Effects on Daily Energy Balance Post Calving

- Significant week of lactation*pre-calving diet*post-calving diet interaction (P<0.001)
Effect of Pre-calving Energy intake on Plasma NEFA Concentration (meq/l)

- Significant pre-calving diet effect in post-calving period (P<0.05)
- Significant week pre calving*pre-calving diet interaction (P<0.001)
Key Findings of this Study

• Pre-calving nutrition can be used as a tool to alter body condition score at calving

• Pre-calving nutrition affects lactational responses to post-calving nutritional management

• The post-calving energy trajectory was significantly influenced by pre-calving nutrition

• Restricted energy intake pre-calving resulted in reduced NEFA concentrations post-calving which indicates reduced body reserve mobilisation
Current On-Farm Research on Pre-calving Nutrition

- 9 commercial farms + 1 research farm (Hillsborough)
# Treatments Imposed

- **5 treatments examined**

<table>
<thead>
<tr>
<th>BCS</th>
<th>BCS range at drying off</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1.0 - 2.5</td>
<td>1   Forage + concentrates for entire dry period</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2   Forage + concentrates for last 3 weeks of the dry period only</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3   Forage only for the entire dry period</td>
</tr>
<tr>
<td>High</td>
<td>2.75 – 5.0</td>
<td>4   Forage + concentrates for last 3 weeks of the dry period only</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5   Forage only for the entire dry period</td>
</tr>
</tbody>
</table>
Early Results
Rapid build up of concentrates in early lactation can cause acidosis

Negative effect on rumen function and forage intake

Slow build up strategies may help overcome these problems and promote forage intake and utilisation

Anecdotal evidence of improved energy balance in early lactation
Study to Examine Concentrate Build-Up Strategy in Early Lactation

Two treatments examined:

- ‘Rapid build-up’ of concentrates in diet
- ‘Delayed build-up’ of concentrate in diet

Basal forages offered

<table>
<thead>
<tr>
<th></th>
<th>Grass silage</th>
<th>Maize silage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (g/kg)</td>
<td>287</td>
<td>310</td>
</tr>
<tr>
<td>Crude protein (g/kg DM)</td>
<td>160</td>
<td>94</td>
</tr>
<tr>
<td>ME (MJ/kg DM)</td>
<td>11.6</td>
<td>11.0</td>
</tr>
<tr>
<td>Starch (g/kg DM)</td>
<td>-</td>
<td>218</td>
</tr>
</tbody>
</table>
**Experimental Treatments**

**Basal diet**
- 15% crude protein
- 35% concentrate (DM basis)
- approx. 7kg concentrate/cow/day

**Rapid build-up**
- Concentrate Intake: 14kg/day

**Delayed build-up**
- Concentrate Intake: 14kg/day

Total diet composition:
- 18% crude protein
- 60% concentrate (DM basis)
- approx. 14kg conc./cow/day
Effect of concentrate build-up strategy on forage intake (grass silage & maize silage)

During the first 18 weeks of lactation, forage intake was significantly higher with cows allocated to the delayed build-up treatment.
During the first 6 weeks of lactation, total DMI was unaffected by concentrate build-up strategy.
During weeks 3-6 of lactation, cows allocated to the delayed concentrate build-up strategy had significantly lower milk yields than those allocated to the rapid build-up strategy.
Effect of concentrate build-up strategy on daily energy balance (day 1-150)

- Delaying concentrate build-up resulted in an earlier return to positive energy balance
## Effect of concentrate build-up strategy on % of cows with one or more incidences of a range of health issues (day 1-150)

<table>
<thead>
<tr>
<th>Health Issue</th>
<th>Rapid Build-up</th>
<th>Delayed Build-up</th>
<th>Odds ratio</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right dilated abomasum (%)</td>
<td>45</td>
<td>18</td>
<td>0.3</td>
<td>0.026</td>
</tr>
<tr>
<td>Mastitis (%)</td>
<td>55</td>
<td>43</td>
<td>0.6</td>
<td>0.352</td>
</tr>
<tr>
<td>Uterine infection (%)</td>
<td>31</td>
<td>32</td>
<td>1.1</td>
<td>0.928</td>
</tr>
</tbody>
</table>
Effect of concentrate build-up strategy on reproductive performance (30 Cows / Treatment)

<table>
<thead>
<tr>
<th></th>
<th>Rapid Build-up</th>
<th>Delayed Build-up</th>
<th>Odds Ratio</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days to onset of luteal activity</td>
<td>33.0</td>
<td>44.8</td>
<td>-</td>
<td>0.136</td>
</tr>
<tr>
<td>Days to 1st service</td>
<td>74.7</td>
<td>76.5</td>
<td>-</td>
<td>0.452</td>
</tr>
<tr>
<td>Conception rate to 1st service (%)</td>
<td>41</td>
<td>36</td>
<td>0.8</td>
<td>0.754</td>
</tr>
<tr>
<td>Overall conception rate (%)</td>
<td>74</td>
<td>86</td>
<td>2.2</td>
<td>0.281</td>
</tr>
</tbody>
</table>
Ongoing Developments In Early Lactation Concentrate Build-Up Strategies

Concentrate Intake (kg/day)

RSU “Rapid Start-up”

ISU “Intermediate Start-Up”

SSU “Slow Start-Up”

Basal diet - 70% grass silage, 30% maize silage (DM basis)
+ concentrate in parlour (cows-6kg, heifers-4.5kg)
- 15% crude protein

Concentrate in Out-of-Parlour feeder (cows-8kg, heifers-6kg)

Calving 10 26 42 Days post calving
Factors Affecting the Response to Concentrate

- Forage quality
- Cow genotype
- Stage of lactation
- Method of offering concentrate
Effect of Silage Quality on the Response to Concentrate Supplementation

- High quality silage
- Medium quality silage

Concentrate intake (kg/day)

Milk yield (kg/cow/day)

- 1 litre/kg
- 0.1 litres/kg
- 0.5 litres/kg
- 1.1 litres/kg
- 1.7 litre/kg
Effect of Cow Genetic Merit on Response to Concentrate Supplementation

Milk yield response of 0.5 litres/kg concentrate

Higher merit

Medium merit

Low merit
Response of Two Different Cow Genotypes to Diverse Nutritional Strategies

(Vance et al., 2011)
Effect of Stage of Lactation on Response to Concentrates

- Historical data with low yielding cows suggests response to concentrate supplementation decreases with stage of lactation.

- Response to additional concentrates at different stages of lactation is less well defined with high-yielding dairy cows.

- Additional concentrates (4.0 kg/cow/day) introduced into the diet at weeks - 2, - 6, - 10 weeks post-calving.
Effect of Offering Additional Concentrate at 2 Weeks Post-calving on Milk Production

![Graph showing milk yield response to concentrate at week 2 of lactation](image)

- Significant milk yield response to concentrate at week 2 of lactation

(Young et al., 2011)
Additional concentrates at week 6 of lactation had no significant effect on milk yield
Effect of Offering Additional Concentrate at 10 Weeks Post-calving on Milk Production

- Diminishing milk yield response to concentrate introduction as stage of lactation increases

(Young et al., 2011)
### Impact of Concentrate Feeding System (Mean Response in Three Separate Experiments)

<table>
<thead>
<tr>
<th></th>
<th>Out of Parlour Feeding</th>
<th>Complete Diet Feeding</th>
<th>% Change due to Complete Diet Feeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrate intake (kg / day)</td>
<td>11.5</td>
<td>11.5</td>
<td>0</td>
</tr>
<tr>
<td>Total DMI (kg / day)</td>
<td>19.0</td>
<td>18.4</td>
<td>-3</td>
</tr>
<tr>
<td>Milk yield (kg / day)</td>
<td>32.7</td>
<td>34.6</td>
<td>+6</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>3.98</td>
<td>3.81</td>
<td>-4</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>3.39</td>
<td>3.38</td>
<td>-0.3</td>
</tr>
<tr>
<td>Fat + protein yield (kg / day)</td>
<td>2.40</td>
<td>2.45</td>
<td>+2</td>
</tr>
</tbody>
</table>

(Gordon et al., 1995; Patterson et al., 1998)
Impact of Concentrate Feeding System

- Previous data suggests that complete diet feeding marginally improves production at a dietary concentrate proportion of 0.60.

- However, these experiments did not involve an easy-feed system for silage.

- Reduced labour in an easy-feed system is one of the benefits of feeding concentrates separately from silage.

- Two different feeding systems examined.
Complete Diet Feeding vs Out-of-Parlour Feeders – Recent Data

Daily complete diet feeding system

Twice weekly feeding of forage via moveable feed barrier
Effect of winter feeding system on cow performance

<table>
<thead>
<tr>
<th>Day 1-146 of lactation</th>
<th>Feeding system</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily complete diet</td>
<td>Twice weekly easy feed</td>
</tr>
<tr>
<td>Total DM intake (kg/day)</td>
<td>18.7</td>
<td>18.5</td>
</tr>
<tr>
<td>Milk yield (kg/day)</td>
<td>30.0</td>
<td>30.6</td>
</tr>
<tr>
<td>Milk fat (%)</td>
<td>4.18</td>
<td>4.02</td>
</tr>
<tr>
<td>Milk protein (%)</td>
<td>3.39</td>
<td>3.39</td>
</tr>
<tr>
<td>Condition score at end of study</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Animal performance was unaffected by feeding system (2 separate experiment) (Ferris et al., 2010)
Take home messages (I)

♦ 11.5% + 14.5% protein in diet is inadequate for high milk production, but a 14.5% protein diet is sufficient for milk production in late lactation

♦ Developments in feeding technology may provide scope to manage cows individually to improve energy balance

♦ Rumen protected methionine offers an opportunity to reduce dietary protein levels and improved N utilisation efficiency, but literature responses appear to be variable
Take home messages (II)

♦ Restricting energy intake pre-calving reduced NEFA concentrations post-calving, indicating reduced body reserve mobilisation

♦ Delaying concentrate build up improved forage intake and reduced metabolic stress with no detrimental effect on performance

♦ Forage quality, cow genotype and stage of lactation all has significant influence on production responses
Innovative and practical management approaches to reduce nitrogen excretion by ruminants

This presentation has been carried out with financial support from the Commission of the European Communities, FP7, KBB-2007-1.

It does not necessarily reflect its view and in no way anticipates the Commission’s future policy in this area.