The Effect of Feed and Stage of Lactation on Milk Processability

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Presentation Guide

Background
Research approach
Milk production
Milk processability
Predicting milk processability (MIR)
Milk Quality ‘Processing’!
Why milk processability?

- Milk urea nitrogen (MUN) concentrations very high in spring 2011
- MUN not beneficial from processing cheese perspective
Milk Proteins

Casein: 78-80% of milk protein
- as1, as2, b and k
- Relatively heat stable
- Aggregation, yoghurt / cheese manufacture

Whey Proteins: 17-20% of milk protein
- Globular, highly folded, a-helices, b-sheets
- b-lactoglobulin (~10% total protein)
- a-lactalbumen (3.7%)
- Other serum proteins: BSA, Ig
- Not heat stable: can aggregate (gel)

Non protein Nitrogen: 5%
Why milk processability?

- Milk urea nitrogen (MUN) concentrations very high in spring 2011
- MUN not beneficial from processing cheese perspective
- What factors affect MUN?
  - Diet affects milk composition (Broderick, 2003) and milk processability (of which heat stability is an indicator) (Singh, 2004)
  - Stage of lactation has an important effect on milk processability (Guinee et al., 1999)
Crude protein

Protein

Undegradable Protein

Degradable Protein

Bacterial protein

Metabolisable protein

Absorbed Protein (PDI)

Used for maintenance, live weight and milk protein

75-80%

Energy

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Ireland and the grass-based system

- Maximum profitability for dairy farms achieved through optimum utilisation of pasture (O'Donovan et al., 2007)
- However, due to grass growth deficits in spring and autumn, and poorer grass quality in autumn, supplementation is required (Burke et al., 2008)
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Research Approach

- Teagasc AGRIC and Teagasc FRC joint research
- Impose diets on dairy cows in spring (early lactation) and autumn (late lactation) to
  - Measure milk production
  - Generate milk from different treatments
    - Measure total milk protein, NPN and Non-casein N using Kjeldahl method
  - Remove fat by ‘Separator’ to make Skim milk
    - Measure protein profile (casein and whey)
  - Measure heat coagulation time on freeze dried samples
Experimental diets

- Spring - early lactation
- Autumn - late lactation
- Grazed grass as the base feed
- With supplementary feed
  - ↓ grazed grass as supplementary feed ↑
- Spring: no grass silage, only concentrate
- Autumn: both feeds considered

- Spring: 4 kg DM high, medium or low CP concentrate feed (+13 kg DM grazed grass)
- Autumn: 13 kg DM grazed grass alone, or with 4 kg DM supplementary feeds - grass, bale silage, pit silage or concentrate
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## Milk production

<table>
<thead>
<tr>
<th>SPRING</th>
<th>13 kg DM grass</th>
<th>4 kg DM concentrate</th>
<th>High CP</th>
<th>Medium CP</th>
<th>Low CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk Yield (kg/d)</td>
<td>27.6</td>
<td>27.0</td>
<td>26.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk Fat (%)</td>
<td>4.5</td>
<td>4.5</td>
<td>4.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk Protein (%)</td>
<td>3.41</td>
<td>3.36</td>
<td>3.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk Solids (kg/d)</td>
<td>2.1</td>
<td>2.1</td>
<td>2.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AUTUMN</th>
<th>17 kg DM grass (HG)</th>
<th>13 kg DM grass (LG)</th>
<th>LG + 4 kg DM bale silage (GB)</th>
<th>LG + 4 kg DM pit silage (GP)</th>
<th>LG + 4 kg DM conc (GC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield (kg/d)</td>
<td>12.4(^a)</td>
<td>11.5(^b)</td>
<td>13.3(^c)</td>
<td>13.3(^c)</td>
<td>15.3(^d)</td>
</tr>
<tr>
<td>Milk fat (%)</td>
<td>4.91</td>
<td>5.08</td>
<td>4.98</td>
<td>4.67</td>
<td>4.79</td>
</tr>
<tr>
<td>Milk protein (%)</td>
<td>3.88</td>
<td>3.76</td>
<td>3.75</td>
<td>3.78</td>
<td>3.88</td>
</tr>
<tr>
<td>Milk solids (kg/d)</td>
<td>1.08(^a)</td>
<td>1.01(^b)</td>
<td>1.12(^a)</td>
<td>1.09(^a)</td>
<td>1.29(^c)</td>
</tr>
</tbody>
</table>
High MUN is an indicator of excess protein in the diet. Low protein diet had lower MUN concentration.
Autumn MUN generally lower than in spring

No effect of treatment on MUN in autumn
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Selecting Milk Composition

…..for Processing!

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# Spring Milk protein fractions

Caseins account for ~80% of total protein - a higher concentration of casein increases cheese yield (Wedholm et al., 2006)

<table>
<thead>
<tr>
<th>13 kg DM grass</th>
<th>4 kg DM concentrate</th>
<th>High CP</th>
<th>Medium CP</th>
<th>Low CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPRING</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Protein Fraction</th>
<th>Concentration (g/l)</th>
<th>High CP</th>
<th>Medium CP</th>
<th>Low CP</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_s$-Casein</td>
<td>11.31$^a$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha_{s2}$-Casein</td>
<td>2.42</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$-Casein</td>
<td>7.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\kappa$-Casein</td>
<td>2.86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$-Lactoglobulin</td>
<td>3.64$^a$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha$-Lactalbumin</td>
<td>0.81</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^a$ indicates significantly higher than $^b$ in the same column.

$\beta$-Lactoglobulin is associated with changes in milk heat stability.

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## Autumn Milk protein fractions

<table>
<thead>
<tr>
<th>AUTUMN</th>
<th>17 kg DM grass (HG)</th>
<th>13 kg DM grass (LG)</th>
<th>LG + 4 kg DM bale silage (GB)</th>
<th>LG + 4 kg DM pit silage (GP)</th>
<th>LG + 4 kg DM conc (GC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_s$-Casein (g/l)</td>
<td>14.2</td>
<td>13.6</td>
<td>14.6</td>
<td>14.2</td>
<td>14.8</td>
</tr>
<tr>
<td>$\alpha_s$-Casein (g/l)</td>
<td>2.79</td>
<td>2.74</td>
<td>2.59</td>
<td>2.70</td>
<td>2.92</td>
</tr>
<tr>
<td>$\beta$-Casein (g/l)</td>
<td>8.63</td>
<td>8.96</td>
<td>10.40</td>
<td>9.20</td>
<td>9.57</td>
</tr>
<tr>
<td>$\kappa$-Casein (g/l)</td>
<td>4.62</td>
<td>4.26</td>
<td>4.19</td>
<td>4.03</td>
<td>4.27</td>
</tr>
<tr>
<td>$\beta$-Lactoglobulin (g/l)</td>
<td>4.83</td>
<td>4.58</td>
<td>4.84</td>
<td>4.68</td>
<td>4.81</td>
</tr>
<tr>
<td>$\alpha$-Lactalbumin (g/l)</td>
<td>0.58$^a$</td>
<td>0.60$^a$</td>
<td>0.67$^b$</td>
<td>0.65$^b$</td>
<td>0.67$^b$</td>
</tr>
</tbody>
</table>

**$\alpha$-Lactalbumin**

- is major protein of human milk $\rightarrow$ ↑ in proportion of $\alpha$-LA in cow’s milk helps it more closely mimic human milk (Lien, 2003)
- is related to production of milk lactose, so may be positively associated with milk yield (Farrell Jr et al., 2004) and therefore be reflective of milk yields of treatments
Spring Milk ‘powder’ heat stability

\[ \uparrow \text{HCT} \Rightarrow \uparrow \text{ability to undergo thermal processing without coagulation (Singh, 2004)} \]
Consequences of low Heat stability - Fouling / Burn on

Protein (whey protein - denaturation/aggregation)
Protein (casein protein – precipitation, instability)
Increase in viscosity, back pressure on heat exchanger, etc.

Poor processability (protein burn on)
- Manufacturing downtime

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Predicting Processability?

Mid-infrared Spectrometry
# Breed quality data base (n=730)

## Basic Composition
- Fat
- Protein
- Casein
- Urea
- Lactose
- Total Solids

## Amino Acids
- Cysteic Acid
- Aspartic Acid
- Threonine
- Serine
- Glutamic Acid
- Glycine
- Alanine
- Cysteine
- Valine
- Methionine
- Isoleucine
- Leucine
- Tyrosine
- Phenylalanine
- Histidine
- Lysine
- NH3
- Proline

## Physical
- Casein Micelle size
- Colour
  - Lightness
  - Blueness
  - Yellowness

## Protein Profile
- \( \kappa \)-casein
- \( \alpha\)-s1-casein
- \( \alpha\)-s2-casein
- \( \beta \)-casein
- \( \alpha \)-lactalbumin
- \( \beta \)-lactoglobulin a
- \( \beta \)-lactoglobulin b

## Functional
- Heat stability
- Native pH
- Coagulation Properties
  - Rennet Coagulation time
  - Curd firmness

## Minerals (n=140)
- Full mineral profile
Correlation between gold standard and MIR-predicted traits

- Proteins: 0.39 (beta LG a) to 0.69 (total LG)
- Amino Acids: 0.22 (Threonine) to 0.75 (Glycine)
- Coagulation time (RCT): 0.74
- Milk pH: 0.84
- Heat stability: 0.68
Acknowledgements

- DAFM RSF 11/sf/309 Precision Nutrition
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