Impact of cow feeding system on the composition and quality of milk and dairy products

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Background

• Increased Agri-Food exports important objective of the Irish dairy industry - Food Harvest 2020 and Food Wise 2025

• Environmentally and economically sustainable milk production

• Processors must produce high quality, desirable products for Ireland’s milk markets

• Important to provide information on pasture based milk quality and processability and systems sustainability

• Ireland’s competitive advantage in milk production is based on the efficient production and utilisation of pasture
Grass growth and diet composition

- Grass growth
- Grazed Grass
- Grass silage
- Concentrate (Conc.)

Graph showing:
- Grass growth in kg DM/ha
- Grazed Grass
- Grass silage
- Concentrate

Dates:
- 15-Jan
- 05-Feb
- 26-Feb
- 19-Mar
- 09-Apr
- 30-Apr
- 21-May
- 11-Jun
- 02-Jul
- 23-Jul
- 13-Aug
- 03-Sep
- 24-Sep
- 15-Oct
- 05-Nov
- 26-Nov
- 17-Dec
Profiling milk from Grass

Joint project - Teagasc AGRIC & Food Research Centre at Moorepark

Research Hypothesis:
Pasture based feeding of cows alters the composition, properties and sensory characteristic's of dairy products and produces milk and dairy products which are nutritionally superior than conventional indoor total mixed ration fed counterparts.
Overview
Feeding systems

- Three treatments:
  1. Grass only
  2. Grass clover
  3. Total Mixed Ration (TMR)

- 18 Spring calving dairy cows per treatment
- Three herds cows
- Mid-February to November – full lactation
Experimental Design

30 Unit Milking Parlour

3 segregated 5,000L Refrigerated Tanks
Measurements

**Herbage/Diet**
- Herbage mass
- Clover content
- Diet quality (OMD, CP, NDF, ADF)
- Sward height

**Animal**
- Milk yield
- Gross composition (fat, protein, lactose)
- Milk solids production
- Milk N fractions
- SCC
- MIR - fortnightly
- Animal BCS and BW
- DM intake
- Grazing/feeding behaviour
- Rumen pH, VFA, ammonia, lactic acid

**Environment**
- Nitrate leaching (grazing)
- N balance
- Methane

**Economic**
- Economic analysis of each system

May, July, Sept.
### Herbage production, concentrate fed and dry matter intake

<table>
<thead>
<tr>
<th></th>
<th>Grass only</th>
<th>Grass-clover</th>
<th>TMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrate fed (kg/cow)</td>
<td>245</td>
<td>245</td>
<td>2,593</td>
</tr>
<tr>
<td>Herbage production (kg DM/ha)</td>
<td>13953</td>
<td>13840</td>
<td>-</td>
</tr>
<tr>
<td>Sward clover content (%)</td>
<td>-</td>
<td>21.2</td>
<td>-</td>
</tr>
<tr>
<td>Daily DM intake (kg/cow)</td>
<td>17.3</td>
<td>17.4</td>
<td>18.5</td>
</tr>
</tbody>
</table>
### Milk yield (kg/cow)

<table>
<thead>
<tr>
<th></th>
<th>Grass-only</th>
<th>Grass-clover</th>
<th>TMR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6244</td>
<td>6762</td>
<td>7277</td>
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</table>

### Milk solids yield (kg/cow)

<table>
<thead>
<tr>
<th></th>
<th>Grass-only</th>
<th>Grass-clover</th>
<th>TMR</th>
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<tbody>
<tr>
<td></td>
<td>503</td>
<td>540</td>
<td>575</td>
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</table>

### Daily milk yield (kg/cow)

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<thead>
<tr>
<th></th>
<th>Grass</th>
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<th>TMR</th>
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<tbody>
<tr>
<td></td>
<td>22.41</td>
<td>24.32</td>
<td>26.36</td>
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</table>

### Daily milk solids yield (kg/cow)

<table>
<thead>
<tr>
<th></th>
<th>Grass</th>
<th>Grass-clover</th>
<th>TMR</th>
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<tbody>
<tr>
<td></td>
<td>1.82</td>
<td>1.94</td>
<td>2.08</td>
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</table>

### Milk urea N

<table>
<thead>
<tr>
<th></th>
<th>Grass</th>
<th>Grass-clover</th>
<th>TMR</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>33.64</td>
<td>40.77</td>
<td>30.62</td>
</tr>
</tbody>
</table>
Objectives:

- Examine the effects of cows feeding system on the macro-composition and fatty acid profile of cows milk throughout lactation.

Methodology:

- Bulk milk samples collected from am and pm milking of each herd weekly from March to October 2015.

General Milk Composition (Foss FT 6000)  N-Fractions (Kjeldahl)  Fatty acid profiling (GC-FID)
Feeding system has a significant effect on milk yield & macro nutrients composition throughout lactation

- Perennial Ryegrass feeding system produced milk with significantly ↑ total Solids than TMR
  - ↑ Fat
  - ↑ Crude Protein

Feeding system resulted in significant differences in the NPN and NCN fractions of milk
- GRS feeding produced milk with significantly higher true protein
Pasture based feeding has a beneficial effect on milk fatty acid profile

**Palmitic Acid**

![Bar chart showing the comparison of Palmitic Acid levels between TMR and GRS with P < 0.05](chart1)

**α-linolenic acid**

![Bar chart showing the comparison of α-linolenic acid levels between TMR and GRS with P < 0.05](chart2)

**Linoleic acid**

![Bar chart showing the comparison of Linoleic acid levels between TMR and GRS with P < 0.05](chart3)

**CLA c9t11**

![Bar chart showing the comparison of CLA c9t11 levels between TMR and GRS with P < 0.05](chart4)
Pasture based feeding has a beneficial effect on milk fatty acid profile

- Essential fatty acids.
- Precursors to eicosanoids roles in inflammation
  - n3 derived eicosanoids possess anti-inflammatory
  - n6 derived eicosanoids possess pro-inflammatory properties (Patterson et al., 2012)
- Western diet has resulted in ↑ n6 fatty acid (Molendi-Coste et al., 2010)
- Concomitant increases in chronic inflammatory diseases (Patterson et al., 2012)
  - non-alcoholic fatty liver disease,
  - cardiovascular disease,
  - obesity,
  - inflammatory bowel disease, rheumatoid arthritis and Alzheimer’s disease
- Foods rich in n3 FA could be beneficial in reducing risk of such diseases (Benbrook et al., 2013)

Omega 3

<table>
<thead>
<tr>
<th></th>
<th>TMR</th>
<th>GRS</th>
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<tbody>
<tr>
<td>0</td>
<td>0.2g</td>
<td>0.3g</td>
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<tr>
<td>0.1g</td>
<td></td>
<td></td>
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<tr>
<td>0.2g</td>
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<td>0.5g</td>
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<td>0.6g</td>
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<td>0.7g</td>
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</tr>
<tr>
<td>0.8g</td>
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<tr>
<td>0.9g</td>
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P < 0.05

Omega 6

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<tbody>
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<td>1.5g</td>
<td>1.8g</td>
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<tr>
<td>0.1g</td>
<td></td>
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<tr>
<td>0.2g</td>
<td></td>
<td></td>
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<tr>
<td>0.3g</td>
<td></td>
<td></td>
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<tr>
<td>0.4g</td>
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<td>0.8g</td>
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<td></td>
</tr>
<tr>
<td>0.9g</td>
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P < 0.05
Objectives:
- Examine the effects of cows feeding system on the composition and quality of sweet cream butter.

Methodology:
- Bulk milk samples collected from am and pm milking of each herd over 3 days (approx. 1000L/ herd) for manufacture of butter using pilot plant facilities in Moorepark Technology Ltd
- Butter analysis over 90d storage period included:
  - Texture
  - Colour
  - FAME & FFA
  - Thermal Properties
  - GCMS Analysis
  - Volatile Profile
  - Descriptive & Hedonic Sensory Analysis

Quality characteristics, chemical composition and sensory properties of butter from cows on pasture versus indoor feeding systems
Pasture derived butter is more yellow in colour

Butter colour:

- **L-Value**
- **a-Value**

### β-Carotene Content

- **TMR**
- **GRS**
- **CLV**
Pasture derived butter has increased beneficial nutrients

Palmitic Acid (C16:0)

$P < 0.05$

Omega 3 (n3)

$P < 0.05$

α-Linolenic Acid (C18:3n3) (ALA)

$P < 0.05$

Omega 6 (n6)

$P < 0.05$

CLA (c9t11)
Fatty acid profiling for verification pasture derived dairy products
TMR diet produces harder butter

**Diagram:**

- **TMR**
  - Temperature: 9.51°C, 15.22°C, 17.40°C
- **GRASS**
  - Temperature: 7.49°C, 12.09°C, 15.37°C
- **CLOVER**
  - Temperature: 6.99°C, 11.48°C, 15.37°C

**Legend:**

- # Indicates significant difference
- § Indicates trend difference

**Notes:**

- O'Callaghan and Hennessy; Grass-Fed Dairy Conference 2018
Feeding system has a significant effect on butter volatile profile
Feeding system has a significant effect on butter sensory properties.

O'Callaghan and Hennessy; Grass-Fed Dairy Conference 2018
Impact of pasture versus indoor feeding systems on quality characteristics, nutritional composition, sensory and volatile properties of full-fat Cheddar cheese

Objectives:

- Examine the effects of cows feeding system on the composition and quality of Cheddar Cheese.

Methodology:

- Bulk milk samples collected from am and pm milking of each herd over 3 days (approx. 1000L/herd) for manufacture of Cheddar Cheese using pilot plant facilities in Moorepark Technology Ltd
- Cheddar cheese analysis over 270d storage period included:

Texture  Colour  FAME & FFA

Cheese Proteolysis

Sensory & Volatile properties
Feeding system alters the colour of Cheddar cheese

A

\[ \text{L* Score} \]

\[ P^* = 0.002 \]

\[ \text{Time } P = 0.001 \]

\[ \text{Trt*Time } P = 0.023 \]

B

\[ \text{a* Score} \]

\[ P^* = 0.012 \]

\[ \text{Time } P = 0.001 \]

\[ \text{Trt*Time } P = 0.702 \]

C

\[ \text{b* Score} \]

\[ P^* = 0.001 \]

\[ \text{Time } P = 0.001 \]

\[ \text{Trt*Time } P = 0.171 \]
Feeding system alters the colour of Cheddar cheese

- \( b^* \) values highly correlated with \( \beta \)-carotene content \( (P < 0.001, \text{ Pearson } r = 0.948) \),
- \( L^* \) values, negatively correlated with the \( \beta \)-carotene content \( (P = 0.004; r = -0.841) \)
Pasture feeding has a beneficial effect on cheese nutritional composition.

Vaccenic Acid (C18:1t11)

- TMR: 1.2 g/100 g of fat
- GRS: 4.0 g/100 g of fat

CLA (c9t11)

- TMR: 1.2 g/100 g of fat
- GRS: 3.0 g/100 g of fat

**P < 0.05**

Cheddar cheese consumption required to meet .8g CLA/day

- TMR: 531 g
- GRS: 182 g

O'Callaghan and Hennessy; Grass-Fed Dairy Conference 2018
Oleic-to-palmitic acid ratio was negatively correlated with cheese hardness ($P = 0.031; r = -0.714$) and chewiness ($P = 0.024; r = -0.735$).

Palmitic acid was significantly and positively correlated with hardness and chewiness attributes ($P = 0.005; r = 0.836$ and $P = 0.007; r = 0.816$ respectively).

The increased CLA content of the pasture-derived cheese was also negatively correlated with hardness ($P = 0.002; r = 0.877$), and chewiness ($P = 0.004; r = -0.849$).
Conclusions

I. Diet had a significant effect on animal performance

II. Variations in milk composition linked to feeding system and stage of lactation

III. Pasture-based feeding ↑ fat and ↑ protein content. Grass-only produced milks with better quality ↑ true protein concentrations.

IV. Pasture-derived systems produced butters and Cheddar Cheeses with ↓ lower thrombogenecity scores and ↑ concentrations of CLA_{c9t11} and β-carotene

V. Differences in nutritional, textural, thermal, sensory and volatile properties of butters and Cheddar Cheeses

VI. Sensory panelist data - significantly higher scores for grass-only derived butter in several attributes

VII. Volatile concentrations of Toluene significantly correlated with pasture-derived products.

VIII. Clear separation of milks and dairy products derived from grazed pasture diets to that of TMR systems
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