Effects of dairy cow different feeding systems on milk composition and processability: Outdoor grazing on pasture vs. indoors feeding on TMR

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Teagasc Food Research Centre Moorepark, Fermoy, Co. Cork
Teagasc study on Pasture vs. TMR feeding systems

Profiling milk from Grass: Comparative effects of 3 dairy herd feeding systems

Outdoors grazing on Perennial ryegrass Grass

Outdoors grazing on Ryegrass-White Clover GRC

Indoors on Total Mixed Ration: grass silage, maize silage, concentrates (molasses, soyabean, barley, rapeseed)

TMR
Feeding systems: Studies in 2015 and 2016

2015 Milk

• Study 1
  Milk composition
  (Mid-to-late lactation: 17 June - 26 November)
  − Gross composition
  − Elemental composition
  − Nitrogen fractions
  − Protein profile

Milk processing characteristics
(Mid lactation: 17 June - 21 September)
− Rennet gelation
− Heat stability

Herd milks were sampled every 2-3 weeks

2016 Product manufacture

• Study 2
  Mozzarella cheese making characteristics
  − Mid-lactation 26th May - 11th June 2016
  − Late lactation 14th Oct - 5th Nov 2016

• Study 3
  Low-heat skim milk powder
  − Mid-lactation 5th July - 20th July 2016
  − Late lactation 26th Sept - 8th Oct 2016

  Triplicate trials for both Mozzarella and powder in ML and in LL, with each trial comparing the milk from the 3 different feeding systems

• Study 4
  Low-heat skim milk powder
  − Vitamin B activity in low-heat skim milk powder in mid-lactation (June-July)
Results

- Milk characterization (Study 1)
- Mozzarella cheese (Study 2)
- Low-heat skim milk powder (Study 3)
- Vitamin activity in skim milk powder (Study 4)
Effect of feeding system: Gross composition

- **Grass milk:**
  - higher mean levels of total solids (TS), protein and casein ($P < 0.05$)

- **TMR milk:**
  - higher concentration of lactose ($P < 0.05$)

Lactation period: significant effect on TS, protein, casein and lactose
Effect of feeding system: N fractions

- Feeding system had little, or no, effect on:
  - mean levels of whey protein, NPN (% TN) or urea (32-36 mg/100 g)
  - mean proportions of $\alpha_{s1}$, $\alpha_{s2}$, $\beta$-, or $\kappa$-caseins

Lactation period: had significant effect on NPN (% total N) and urea
Effect of feeding system: macro-elements of milk

- Macro elements measured:
  - Ca, P, Mg and Na

- **Grass milk** had higher mean concentrations of Ca, P and Na
  [effect not observed in later studies]

- The mean ratio of Ca-, P-, Mg-, or Na-to-casein was similar for both milks

Lactation period: significant effect on Ca, P, Mg and Na.
Effect of feeding system: trace elements of milk

- Trace elements measured:
  Zn, Fe, Cu, Mn, Mo, Se and Co

- **TMR milk** had:
  - higher mean concentrations of Se and Cu
  - higher mean ratios of total Zn, Cu and Se-to-casein or to protein

- Grass- and TMR- milks: little, or no, difference in concentrations of Zn, Fe, Mn, Mo or Co

Lactation period: significant effect on Zn, Mo and Co
Effect of feeding system: rennet gelation and heat stability

- **Grass milk** had stronger rennet gelation than **TMR milk**
  - higher gel-firming rate \( (dG'/dt) \)
  - higher gel firmness at 40 min, \( G'_{40} \)

- Feeding system did not significantly effect:
  - heat coagulation time (HCT) at 140 °C in pH range 6.2-7.2
  - \( HCT_{npH}, HCT_{max}, HCT_{min} \)
Results

- Milk characterization (Study 1)
- Mozzarella cheese (Study 2)
- Low-heat skim milk powder (Study 3)
- Vitamin activity in skim milk powder (Study 4)
Effect of feeding system: Cheese milk

- **Grass milk:**
  - higher mean concentrations of protein and casein

- **TMR milk:**
  - higher mean concentrations of I, Cu and Se
  - higher mean ratios of I, Cu and Se-to-casein

<table>
<thead>
<tr>
<th>Item</th>
<th>Grass</th>
<th>TMR</th>
</tr>
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<tbody>
<tr>
<td>Protein (%)</td>
<td>3.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.38&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>Casein (%)</td>
<td>2.97&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.72&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>I (µg/kg)</td>
<td>184&lt;sup&gt;b&lt;/sup&gt;</td>
<td>943&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>Cu (µg/kg)</td>
<td>51&lt;sup&gt;b&lt;/sup&gt;</td>
<td>83&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Se (µg/kg)</td>
<td>21.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.5&lt;sup&gt;a&lt;/sup&gt;</td>
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</table>

Data was analysed by SAS using one way ANOVA with post hoc Tukey testing. Values within a row not sharing a common superscript differ significantly \((P < 0.05)\).

- Feeding system did not affect:
  - concentration of lactose or macroelements (Ca, P, Mg, Na)

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<tr>
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<tr>
<td>Lactose (%)</td>
<td>4.61</td>
<td>4.68</td>
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<tr>
<td>Ca (mg/100g)</td>
<td>122</td>
<td>116</td>
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<tr>
<td>P (mg/100g)</td>
<td>91</td>
<td>92</td>
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</table>

Values within a row without a superscript did not differ significantly \((P > 0.05)\).

Lactation period: significant effect on protein, casein, lactose, Ca, Mg, Zn, I, Cu, Mo and Se
Effect of feeding system: Mozzarella cheese

- Feeding system had no effect on levels of moisture, fat, protein, salt, Ca or P in cheese

- Cheese from TMR milk had higher levels of I, Cu and Se

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<td>Moisture (%)</td>
<td>47.4</td>
<td>46.7</td>
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<tr>
<td>Protein (%)</td>
<td>28.5</td>
<td>28.1</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>20.8</td>
<td>21.0</td>
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<tr>
<td>S/M (%)</td>
<td>3.56</td>
<td>3.67</td>
</tr>
<tr>
<td>Ca (mg/100g)</td>
<td>855</td>
<td>827</td>
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<tr>
<td>P (mg/100g)</td>
<td>564</td>
<td>552</td>
</tr>
<tr>
<td>I (µg/kg)</td>
<td>356^b</td>
<td>2253^a</td>
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<tr>
<td>Cu (µg/kg)</td>
<td>459^b</td>
<td>716^a</td>
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<tr>
<td>Se (µg/kg)</td>
<td>114^b</td>
<td>204^a</td>
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</table>

Data was analysed by SAS using one way ANOVA with post hoc Tukey testing. Values within a row not sharing a common superscript differ significantly ($P < 0.05$). Values within a row without a superscript did not differ significantly ($P > 0.05$). S/M = Salt-in-moisture

Lactation period: significant effect on moisture, protein, fat, Zn, Cu and Mo
Effect of feeding system: Mozzarella cheese

- Feeding system
  - no effect on recoveries of protein or fat from milk to cheese
  - Grass milk had higher actual yield in both mid- and late-lactation
  - no effect on normalized yield*

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<tr>
<th>Item</th>
<th>Mid lactation</th>
<th></th>
<th>Late lactation</th>
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<td></td>
<td>Grass</td>
<td>TMR</td>
<td>Grass</td>
<td>TMR</td>
</tr>
<tr>
<td>Protein recovery (%)</td>
<td>76.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>76.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>75.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>77.4&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fat recovery (%)</td>
<td>72.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>75.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>71.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>73.8&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Actual yield, $Y_a$ (kg/100 kg milk)</td>
<td>9.3&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.7&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Normalised yield, $Y_n$ (kg/100 kg milk)</td>
<td>9.2&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.6&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.5&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Data was analysed by SAS using one way ANOVA with post hoc Tukey testing. Values within a row not sharing a common superscript differ significantly ($P < 0.05$). *Normalized yield: predicted yield, where fat and protein levels are hypothetically standardized across all milks.

Lactation period: significant effect on actual yield ($Y_a$)
Effect of feeding system: Mozzarella cheese

Cheeses stored at 4 °C and evaluated at 1, 10, 20, 30 and 50 day

- Effect of feeding system on **unheated cheese**
  - Little, or no, effect on the levels of proteolysis, water binding capacity or texture (firmness, cohesiveness, chewiness) during storage
  - Significant impact on colour: cheese from Grass milk was significantly ‘yellower’
    - lower a* and higher b* colour coordinate values
Effect of feeding system: Mozzarella cheese

- Effect of feeding system on **heated cheese** (95 °C):
  - Cheese from **Grass milk** had higher mean flowability and fluidity (LT_max) than cheese from TMR milk
  - Grass milk cheese spreads better and is less gummy on heating

- Did not affect extension energy (~ stringiness) and congealing temperature (on cooling from 95 to 25 °C).
Results

- Milk characterization (Study 1)
- Mozzarella cheese (Study 2)
- Low-heat skim milk powder (Study 3)
- Vitamin activity in skim milk powder (Study 4)
Effect of feeding system: Low-heat skim milk powder

- **Grass powder:**
  - higher mean levels of protein and casein

- **TMR powder:**
  - higher mean contents of lactose, I, Cu and Se

- No effect of feeding system on mean contents of Ca and P

- **Grass powder**
  - Greener (lower a*) and yellower (higher b*) hues than TMR powder.

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<tr>
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<tbody>
<tr>
<td><strong>Composition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein (%)</td>
<td>40.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38.1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Casein (%)</td>
<td>31.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>49.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>52.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>I (µg/kg)</td>
<td>497&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5568&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Cu (µg/kg)</td>
<td>723&lt;sup&gt;b&lt;/sup&gt;</td>
<td>937&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Se (µg/kg)</td>
<td>213&lt;sup&gt;b&lt;/sup&gt;</td>
<td>373&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ca (mg/100g)</td>
<td>1275&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1273&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>P (mg/100g)</td>
<td>1027&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1123&lt;sup&gt;a&lt;/sup&gt;</td>
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<thead>
<tr>
<th><strong>Colour</strong></th>
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<tbody>
<tr>
<td>a* (green-red)</td>
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<tr>
<td>b* (blue-yellow)</td>
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Values within a row not sharing a common superscript differ significantly (P < 0.05).
Effect of feeding system: Reconstituted skim milk (RSM)

Composition of RSM (10%, w/w)

- **Grass RSM:**
  - higher mean concentrations of protein, casein and [Ca\(^{2+}\)]

- **TMR RSM:**
  - higher mean contents of lactose and NPN (% total N)

- No effect of feeding system on:
  - casein number, proportion of individual caseins or urea.
  - casein micelle size
  - casein micelle hydration

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<tr>
<td>Total protein (%)</td>
<td>4.05(^a)</td>
<td>3.81(^b)</td>
</tr>
<tr>
<td>Casein (%)</td>
<td>3.18(^a)</td>
<td>3.03(^b)</td>
</tr>
<tr>
<td>Ionic calcium, <a href="mM">Ca(^{2+})</a></td>
<td>1.37(^a)</td>
<td>1.19(^b)</td>
</tr>
<tr>
<td>Lactose (%)</td>
<td>4.91(^b)</td>
<td>5.20(^a)</td>
</tr>
<tr>
<td>NPN (% total N)</td>
<td>4.96(^b)</td>
<td>5.34(^a)</td>
</tr>
</tbody>
</table>

Values within a row not sharing a common superscript (a, b) differ significantly \((P < 0.05)\)

Casein number 78.5 79.5

Individual caseins (% total)

- \(\alpha_s1 + \alpha_s2\)-casein 48.3 48.1
- \(\beta\)-casein 41.7 42.0
- \(\kappa\)-casein 10.0 9.87

Urea (mg/100g) 46.6 44.4

**Physicochemical characteristics**

- Casein micelle size (nm) 182 176
- Casein hydration (g water/g casein) 3.08 3.10

Values within a row without a superscript did not differ significantly \((P > 0.05)\)
Effect of feeding system: Reconstituted skim milk (RSM)

Processability of RSM

- Affected rennet coagulability:
  Grass RSM had overall stronger rennet gel strength at 40 min ($G'_{40}$) than TMR RSM

- Little, or no, effect on:
  - heat coagulation time (HCT)/pH profile
    - All milks type pH/HCT curves
  - ethanol stability-pH profile
Effect of feeding system: Reconstituted skim milk

Stirred yoghurt manufacture and properties: (14.5% TS, 2.3% fat)

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<tr>
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</thead>
<tbody>
<tr>
<td>Storage modulus at pH 4.6 (Pa)</td>
<td>355</td>
<td>357</td>
</tr>
<tr>
<td>Time to reach pH 4.6 (min)</td>
<td>276</td>
<td>278</td>
</tr>
<tr>
<td><strong>Yield stress</strong> (σ₀, Pa)</td>
<td>8.1</td>
<td>7.4</td>
</tr>
<tr>
<td><strong>Consistency index</strong> (K, Pa.sⁿ)</td>
<td>1.00</td>
<td>3.02</td>
</tr>
<tr>
<td><strong>Flow behaviour index</strong> (n, -)</td>
<td>0.68</td>
<td>0.47</td>
</tr>
<tr>
<td>Viscosity at 120s⁻¹ (Pa.s)</td>
<td>210</td>
<td>208</td>
</tr>
<tr>
<td>WHC at 300 g (g serum retained/g yoghurt)</td>
<td>75</td>
<td>80</td>
</tr>
</tbody>
</table>

Values within a row without a superscript did not differ significantly (P > 0.05).

- Feeding system had no effect on flow behaviour, viscosity, or water-holding capacity of yoghurt.
Results

- Milk characterization (Study 1)
- Mozzarella cheese (Study 2)
- Low-heat skim milk powder (Study 3)
- Vitamin activity in skim milk powder (Study 4)
Effect of feeding system: vitamin concentration in skim milk powder

• Significantly higher vitamin B2 (riboflavin) in Grass sample than in TMR sample.

• Significantly higher vitamin B3-amide (niacinamide) in TMR sample than in Grass sample.

Average concentrations (μM) of water-soluble vitamins for perennial ryegrass (GRS), perennial ryegrass/white clover (CLV) and total mixed ration (TMR) diets. Values within each series cluster not sharing a common letter differed significantly.
Effect of feeding system: vitamin concentration in skim milk powder

- Significantly higher vitamin B7 (biotin) in Grass sample than in TMR sample.

Average concentrations (μM) of water-soluble vitamins for perennial ryegrass (GRS), perennial ryegrass/white clover (CLV) and total mixed ration (TMR) diets. Values within each series cluster not sharing a common letter differed significantly.
Key differences between grazing on Grass vs. indoor feeding on TMR

Compared to **TMR feeding**, gazing on **Grass** g was characterized by the following:

- **Milk:**
  - higher concentrations of protein, casein, and lower concentrations of lactose, I, Se, and Cu
  - stronger rennet gelation

- **Mozzarella cheese with:**
  - higher cheese-yielding capacity
  - lower of levels of I, Se and Cu, and a more yellow colour
  - higher flow and fluidity on heating to 95°C

- **Low-heat skim milk powder with:**
  - higher contents of protein (~2-3%) and vitamins B2 and B7, and lower contents of lactose (~3%), I, Cu, Se and Vitamin B3-amide
  - a more green-yellow hue
  - stronger rennet gelation when reconstituted to 10% (w/w)
  - similar physicochemical, heat-stability, ethanol-stability and yoghurt-making characteristics on reconstitution

Effects varied somewhat with lactation period.
Study Implications

• Feeding system affected nutrients in milk
  – to degree depending on stage of lactation and year of study

• Feeding system affected some processability parameters (rennet gelation, actual cheese yield, cheese meltability, colour of cheese and SMP) but not others (heat stability, ethanol stability, or yoghurt-making properties of milk or reconstituted skim milk power)

• Effects of feeding system on processability and products can be explained by:
  – high concentrations of protein, β-carotene and vitamin B2 (riboflavin) in Grass milk
  – low concentration of lactose in Grass milk
  – similar ratio of macroelements-to-casein in all milks

• Effects on rennet gelation and actual cheese-yielding capacity could probably be eliminated by milk protein standardization, e.g., by ultrafiltration

• Colour effects and different ratio of trace elements (I, Cu, Se)-to-protein associated with milk feeding system - more difficult to mask
  – Mozzarella cheese
  – Nutritional beverages with target ratios of trace elements to protein
Detailed results available in publications

Grass Science in Europe 23: 709-711

Effect of dairy cow feeding system on milk composition and processability

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Grazing of dairy cows on pasture versus indoor feeding on total mixed ration: Effects on low-moisture part-skim Mozzarella cheese yield and quality characteristics in mid and late lactation

Arunima Gulati,† Norann Galvin,‡ Deirdre Hennessy,‡ Stephen McAuliffe,‡§ Michael O’Donovan,‡ Jennifer J. McManus,† Mark A. Fenelon,† and Timothy P. Guinee°†

Dairy cow feeding system alters the characteristics of low-heat skim milk powder and processability of reconstituted skim milk

<table>
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<th>Journal of Dairy Science</th>
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<td>Date Submitted by the Author:</td>
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<td>Complete List of Authors:</td>
<td>Gulati, Arunima; Teagasc Food Research Centre Moorepark, Food Chemistry and Technology. Hennessy, Deirdre; Teagasc, Grassland Science Research Department. O’Donovan, Michael; Teagasc, Moorepark, Dairy Production. McManus, Jennifer; Maynooth University, Department of Chemistry. Fenelon, Mark A.; Teagasc Food Research Centre, Food Chemistry &amp; Technology.</td>
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Thank You