Infant milk formula: Manufacture and novel ingredients

Shane Crowley
Infant milk formula in Ireland

- Infant Milk Formula (IMF) market is valued at US $10bn.
- Market is growing at ~15% per year (growth in Asia is higher)
- Key IMF producers in Ireland supply **15% of IMF globally** and **40% of IMF in EU**
What is infant formula?

• A human milk analogue
• Made with bovine milk proteins (mostly)
• Complex mixture of ingredients
• Efforts at humanisation ongoing
# Infant formula: Fundamentals of ingredient requirements

<table>
<thead>
<tr>
<th>Component</th>
<th>Bovine Milk</th>
<th>Human Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total solids</strong></td>
<td>12.5%</td>
<td>12.9%</td>
</tr>
<tr>
<td><strong>Protein</strong></td>
<td>3.5%</td>
<td>1.0%</td>
</tr>
<tr>
<td><strong>Whey:Casein ratio</strong></td>
<td>20:80</td>
<td>60:40</td>
</tr>
<tr>
<td><strong>Fat</strong></td>
<td>3.8%</td>
<td>4.1%</td>
</tr>
<tr>
<td><strong>Carbohydrate</strong></td>
<td>4.8%</td>
<td>7.2%</td>
</tr>
<tr>
<td><strong>Ash</strong></td>
<td>0.7%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

**Note:** High α-lac, high β-CN, Little α-CN, No β-lg
Fortification of reconstituted skim milk powder with different calcium salts: Impact of physicochemical changes on stability to processing

Shane V. Crowley, Alan L. Kelly, James A. O’Mahony

- Various Ca salts added to 3.0% protein skim milk at 500 mg L\(^{-1}\)
- Adjusted to pH 6.8 (except for pH measurement and pH-HCT)

<table>
<thead>
<tr>
<th></th>
<th>pH (-)</th>
<th>Ionic calcium (mM)</th>
<th>Casein micelle size (nm)</th>
<th>Sedimentation rate (mm day(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.75(^{b})</td>
<td>1.41(^{c})</td>
<td>201(^{b})</td>
<td>0.065(^{c})</td>
</tr>
<tr>
<td>CCarb</td>
<td>6.76(^{b})</td>
<td>1.43(^{c})</td>
<td>201(^{b})</td>
<td>0.066(^{c})</td>
</tr>
<tr>
<td>CPhos</td>
<td>6.75(^{b})</td>
<td>1.45(^{c})</td>
<td>201(^{b})</td>
<td>0.066(^{c})</td>
</tr>
<tr>
<td>CCit</td>
<td>6.75(^{b})</td>
<td>1.46(^{c})</td>
<td>207(^{b})</td>
<td>0.066(^{c})</td>
</tr>
<tr>
<td>CChlor</td>
<td>6.34(^{c})</td>
<td>4.37(^{a})</td>
<td>199(^{b})</td>
<td>0.088(^{b})</td>
</tr>
<tr>
<td>CGluc</td>
<td>6.47(^{c})</td>
<td>3.74(^{ab})</td>
<td>199(^{b})</td>
<td>0.086(^{b})</td>
</tr>
<tr>
<td>CHyd</td>
<td>8.77(^{a})</td>
<td>3.06(^{b})</td>
<td>230(^{a})</td>
<td>0.100(^{a})</td>
</tr>
</tbody>
</table>

\(^{a-c} P < 0.05\)

Heat stability and heat-induced changes

NB: Fouling, Feed η for drying

Heat Stability (good thing!)
Heat stability of model infant milk formulae with altered whey protein profiles

Shane V. Crowley, Aisling P. Dowling, James A. O’Mahony

Reconstituted in SMUF to 5.5% protein with 60:40 WP:CN

Note: β-lg responsible for many undesirable changes during thermal processing

-> high α:β = more humanised
Heat stability

Heat coagulation time at 140°C (min)

pH

α-lac:β-lg ratio
Heat-induced changes

- Heating-cooling cycle with rheometer
- Post-heating analysis
  - Particle size
  - Protein profile
  - Physical stability

![Graph showing temperature vs. time with different colors indicating low and high α:β ratios.]

![Graph showing viscosity vs. time with different colors indicating low and high α:β ratios.]

![Graph showing casein micelle size vs. intensity with different markers indicating 0%, 25%, and 50% α-lac.]
Protein-enrichment characteristics of different polymeric membranes during filtration of skim milk at refrigeration temperatures

Shane V. Crowley, Veronica Caldeo, Noel A. McCarthy, Mark A. Fenelon, Alan L. Kelly and James A. O’Mahony
Protein-enrichment characteristics of different polymeric membranes during filtration of skim milk at refrigeration temperatures

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TIGHT

1000 kDa PES membrane (●)

0.1 µm PVDF membrane (■)

LOOSE

0.45 µm PVDF membrane (♦)

• Slightly increased β:α-CN ratio using wider pore-size membrane (but poor β-CN purity)
• Good β-CN purity (>80% of total CN*) with tighter membranes (but loss of LF)
• Resultant ingredient has excellent functionality in itself²

... But, for infant formula the question is:

how do we get the β-lg out?


* From RP-HPLC data (not shown)
Negatively-charged membranes for β-lg removal

<table>
<thead>
<tr>
<th>Protein</th>
<th>Bovine milk (g L⁻¹)</th>
<th>Human milk</th>
<th>Isoelectric point (pH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>β-lg</td>
<td>3.2</td>
<td>0</td>
<td>5.2</td>
</tr>
<tr>
<td>α-lac</td>
<td>1.2</td>
<td>2.5</td>
<td>4.4</td>
</tr>
<tr>
<td>β-CN</td>
<td>8.6</td>
<td>3.9</td>
<td>4.6</td>
</tr>
</tbody>
</table>
Thank you.

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Also, if anyone’s interested: