Characteristics in milk influencing cheese yield and cheese quality

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- What is cheese?

- What is a good cheesemilk?
What is cheese?

Cheese is the ripened or unripened soft or semi-hard and extra hard product, which may be coated, and in which the whey protein/casein ratio does not exceed that of milk, obtained by:

a) Coagulating wholly or partly the protein of milk, skimmed milk, partly skimmed milk, cream, whey cream or buttermilk, or any combination of these materials, through the action of rennet or other suitable coagulating agents, and by partially draining the whey resulting from such coagulation; and/or

b) Processing techniques involving coagulation of the protein of milk and/or products obtained from milk which give an end-product with similar physical, chemical and organoleptic characteristics as the product defined under a).

Milk proteins (cow milk)

Nitrogen-containing compounds 100%

- **Protein**: 95%
  - NPN 5%
  - Whey protein (ca 20%)
  - Casein (ca 80%)
    - αs1-casein
    - αs2-casein
    - β-casein
    - κ-casein

β-lactoglobuline
α-lactalbumine
Immunoglobuline
Serum albumine
The hairy casein micelle

- Hairy layer of negatively charged κ-casein on the outside
- \( \alpha_{S1}, \alpha_{S2} \) and β casein hidden in the core
- Nanoclusters of Ca-Phosphates binds the casein-molecules

\[
\text{CCP} \quad \text{Ca}^{2+} + \text{H} \left( \text{PO}_4 \right)^{2-} \\
\text{H} \left( \text{PO}_4 \right)^{2-} + \text{H}^+ \quad \text{H}_2 \left( \text{PO}_4 \right)^{-}
\]
Coagulation of milk

Coagulation

Gel formation

Syneresis & contraction

Slow proteolysis

Enzymatic phase

Rennet addition

Clotting point

Cutting

Moulding
Gel formation starts with the formation of strands of micelles.
Coagulation of milk

Rennet addition → Clotting point → Cutting → Moulding

Enzymatic phase → Coagulation → Gel formation

Syneresis & contraction → slow proteolysis
From milk to cheese

Milk -> Coagulum -> Cheesemaking -> Cheese

Cheesemaking:
- Cutting
- Stirring
- Scalding

Cheese:
- Moulding
- Salting
- Ripening

Starter Rennet
Cheese yield

- Kg of cheese pr 100 kg of milk → % yield
- Litre of milk to produce 1000 tonnes of cheese

Cheese yield is one of the keys to improve the economy of cheese production.
## Transfer of protein from milk to cheese

<table>
<thead>
<tr>
<th>Description</th>
<th>kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casein in milk and starter</td>
<td>100</td>
</tr>
<tr>
<td>Increase due to pasteurisation and bactofugation</td>
<td>+ 1</td>
</tr>
<tr>
<td>Cheese fines</td>
<td>- 0.5</td>
</tr>
<tr>
<td>Addition from whey</td>
<td>+ 0.21</td>
</tr>
<tr>
<td>Loss during brining</td>
<td>- 0.02</td>
</tr>
<tr>
<td>Moisture binding due to hydrolysis (first 12 dg)</td>
<td>+ 0.18</td>
</tr>
<tr>
<td><strong>Sum protein in the cheese after 12 days</strong></td>
<td><strong>100.9</strong></td>
</tr>
</tbody>
</table>

Van den Berg et al. 1996
Theoretical cheese yield – formula for Cheddar

- Van Slyke

\[
\frac{(0.93F + C - 0.1) \times 1.09}{100 - W} \times 100
\]

**F**: Fat in milk, %

**C**: Casein in milk, %

**W**: Water content of cheese, %

**0.1**: Constant for loss of cheese fines

**1.09**: Constant representing the retention of soluble salts, lactose and salt addition
Factors in milk influencing cheese yield

- Protein content
- Genetic variants
- Leakage of CCP and β-casein during cold storage
- Somatic cell count
- Psychotropic bacteria
- Seasonal variation
- Lactation
Protein content

\[
\frac{(0.93F + C - 0.1) \times 1.09}{100 - W} \times 100
\]

Yield increase with increased protein content, but not always……
Protein content is an important factor in breeding programs

- From 1970-1996 milk yield in Sweden increased by >60%.

  Lindmark-Mansson et al. (2003)

  - The protein content remained constant
    - The amount of casein was reduced
    - The amount of whey proteins were increased.
    - Prevalence of β-Lg A
      - Associated with higher protein content and higher milk yield (Klantschitsch et al. 2000).
Protein content is an important factor in breeding programs

- **Different breeds differs in protein and fat content**
  
  - Jersey milk has higher protein and fat content than Fresian milk (Auldist et al. 2004).
    
    - Jersy milk has better cheesemaking properties
    - Totally related to the total solid composition of the milk
      - no connection to the genotype of K-Cn. (Auldist et al. 2004)
Breed for BB variant of β-lg and κ-Cn!

- **A general conclusion from several studies**
  
  (van den Berg et al., 1996; Walsh et al., 1998)
  
  - Best cheesemaking abilities is obtained with the BB variant of β-Lg and κ-Cn

- **Milk with the BB variant of β-Lg**
  
  - has a higher casein to total protein ratio
  
  - a higher casein content

- **Milk with the BB variant of κ-Cn**
  
  - higher casein level
  
  - higher κ-Cn content,
    
    - resulting in smaller micelles
      
      - shorter rennet coagulation times
      
      - higher curd firmness
Composite milk protein phenotypes - importance for cheesemaking properties

- **The perfect combination does not exist**
  - no combination gave the lowest fat in whey, lowest cheese fines, highest yield and the highest proteolysis.

- **Cheese yield**
  - Interaction by gene locki
  - **Highest cheese yield** $\beta$-cn $A^2B$, $K$-cn $AA$, $\beta$-lg $AA$
  - Lowest cheese yield $\beta$-cn $A^2A^2$, $K$-cn $AA$, $\beta$-lg $AA$ (30 % lower yield)

- **Renneting:**
  - $K$-cn $BB$ best rennetability

- **Fat in whey**
  - Lowest fat in whey with $\beta$-cn $A^2B$, $K$-cn $AA$, $\beta$-lg $BB$ or $\beta$-cn $A^2A^2$, $K$-cn $AA$, $\beta$-lg $BB$

- **Cheese fines**
  - Lowest amounts in whey with $\beta$-cn $A^2B$, $K$-cn $AA$, $\beta$-lg $BB$ or $\beta$-cn $A^2B$, $K$-cn $BB$, $\beta$-lg $BB$

Mayer et al. (1997)
Poor coagulation properties

- Milk samples resulting in a weak coagulum had:
  - Low concentration of K-Cn
  - Low proportion of K-Cn in proportion to total casein.
  - Milk having the AA genotype of K-Cn had lower concentrations of K-Cn than milk having the AB genotype.
  - High frequency of K-Cn AE in milk with poor coagulation properties.

Wedholm et al. (2006)
Leakage of CCP and β-casein during cold storage

Reimerdes & Klostermayer (1976)
Somatic cell count

- Milk with a high somatic cell count (SSC) reduces cheese yield as this milk is associated with (Auldist et al. 1996):
  - higher proteolytic activity
  - lower concentration of fat and casein
  - a higher content of serum albumin and immunoglobulin
- The somatic cells contain a plasmin activator that converts plasminogen to plasmin in the mammary gland (Lucey & Kelly, 1994).
  - Plasmin degrades mainly \(\beta\) and \(\alpha_{S2}\) –casein into peptides,
  - this reaction is still active at 5 °C,
- Based on results showing a marked decrease in yield at cell counts > 100,000 pr ml. milk, Barbano et al. (1991) suggests this as the upper limit for SSC for cheese milk.
Psychrotrophic bacteria in raw milk

- **Total counts in raw milk**
  - In the range $10^4$-$10^6$ cfu/ml (Sørhaug & Stepaniak 1991).

- **Fresh milk - mesophilc flora**
  - 1 to 10% of the total count is psychrotrophic bacteria

- **Stored milk - Total flora > $10^4$ cfu/ml**
  - the flora is dominated by Gram-, lactose- psychrotrophic bacteria
Psychrotrophic bacteria- growth

- **Average generation time at 4 °C between 4,5 and 11 hours**
  (Sørhaug & Stepaniak, 1991).

- **Critical storage time for raw milk is between 60 and 72 hours between 2 and 4 °C**
  (Suhren 1989).
  - Thermisation is often used at arrival when the dairy plant needs to store the raw milk longer than 2 days.

- **An experiment on Norwegian and Swedish raw milk showed:**
  (Ternström et al. 1993)
  - If CFU > 10^7 pr ml milk, The psychrotrophic flora totalled 80 % of the microflora
    - *Pseudomonas (P.). fluorescens* biovar 1 and biovar 3,
    - *P. fragi*
    - *P. lundensis.*
Psychrotrophic bacteria – proteases and lipases

- Psychrotrophic bacteria produce heat resistant extracellular proteases and lipases
  - May cause severe problems with hydrolysis of α-, β- and κ-caseins
    - (Mottar, 1989, Kohlmann et al. 1991)

- Proteases produced by *P. fluorescens* M3/6 stimulated plasminogen activators
  - Transformation of plasminogen to plasmin.
    - (Frohbieter et al. 2005)
Changes in milk composition during lactation

Figure 3-1 Changes in the concentrations of fat (○), protein (■), and lactose (○) in milk during lactation.

Fox et al. 2000
Effect of lactation on protein and yield:

- protein,
- real yield (lm-mozzarella),
- calculated yield

NL: normal lactation, LL: late lactation, VLL: very late lactation

Guinee et al. 2006
Changes in plasmin during lactation (Baldi et al., 1996)

### TABLE 3

<table>
<thead>
<tr>
<th>Activity (Units/ml)</th>
<th>Month</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Plasmin</td>
<td>5.46b</td>
<td>5.49b</td>
</tr>
<tr>
<td>Plasminogen</td>
<td>32.95b</td>
<td>30.66b</td>
</tr>
<tr>
<td>Plasminogen activator</td>
<td>206.95b</td>
<td>296.92b</td>
</tr>
<tr>
<td>Pg/Pl</td>
<td>6.03a</td>
<td>5.58a</td>
</tr>
</tbody>
</table>

Means followed by the same letter within the same row were not significantly different from each other (P < 0.05).

- Plasminogen activator
- Plasminogen activator inhibitor
- Plasminogen
- Plasmin
- Plasmin inhibitor
- Casein
- Degraded Casein
Seasonal variation

- Due to lactation
  - calving concentrated at one or two times of the year
  - Australia, New Zealand, Ireland very clear seasonal pattern due to lactation
  - Quality of feed more important than lactation (Kefford et al., 1995).

- Due to climate
  - Winter – indoor, silage, hay
  - Summer - outdoor pasture
  - Norway and Sweden very clear seasonal patterns due to climate
## Effect of free fatty acids on the renneting properties of milk

<table>
<thead>
<tr>
<th>Fatty acids (4000 ppm)</th>
<th>Clotting time (sek)</th>
<th>Firmness (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 control</td>
<td>57</td>
<td>68</td>
</tr>
<tr>
<td>0 + 20 mM Ca(^{2+})</td>
<td>51</td>
<td>72</td>
</tr>
<tr>
<td>Caproic C6:0</td>
<td>84</td>
<td>49</td>
</tr>
<tr>
<td>Caprylic C8:0</td>
<td>140</td>
<td>16</td>
</tr>
<tr>
<td>Capric C10:0</td>
<td>- (did not clot)</td>
<td>-</td>
</tr>
<tr>
<td>Capric + 20 mM Ca(^{2+})</td>
<td>52</td>
<td>49</td>
</tr>
<tr>
<td>Lauric C12:0</td>
<td>- (did not clot)</td>
<td>-</td>
</tr>
<tr>
<td>Lauric + 20 mM Ca(^{2+})</td>
<td>44</td>
<td>51</td>
</tr>
<tr>
<td>Palmitic C16:0</td>
<td>69</td>
<td>33</td>
</tr>
<tr>
<td>Oleic C18:1</td>
<td>71</td>
<td>12</td>
</tr>
<tr>
<td>Oleic + 20 mM Ca(^{2+})</td>
<td>48</td>
<td>59</td>
</tr>
</tbody>
</table>

(Jenkins, 1984)
Influence of lactation on free fatty acids in cheese

Fig. 3. Total levels of free fatty acids (FFA) in cheeses made from early (○), mid (■) and late (▲) lactation milk. The values presented are the means of triplicate trials.

Hickey et al, 2006
What is a good cheese milk?

- Good cheesemaking properties
  - Acidification
  - No antimicrobial agents
  - Renneting
- High cheese yield
  - Kg of cheese pr. 100 kg of milk
- Good substrate for the cheese ripening process
  - Presence of NSLAB
  - Absence of spoilage bacteria
  - Influence from feed
Amino acid metabolism

result 1, x-expl: 78%, 15%

Skeie & Ardö (2000)

www.umb.no
Absence of pathogenic and clostridium bacteria

- **Pathogens**
  - Those that may survive in cheese are spoiled by pasteurisation
  - In milk for raw milk cheeses the presence of *Staphylococcus aureus* should be focused as it is usually present in milk from cows with mastitis and survive in cheese. (Bachmann & Spahr, 1995; Spahr & Url, 1994)

- **Clostridium**
  - *Clostridium tyrobutyricum*, an anaerobic sporeforming bacteria which produces butyric acid, CO₂ and H₂ from lactic acid- causes late blowing on the hot ripening room in cheeses with eyes (pH >5.3), but also to cheeses with closed texture these bacteria produce inedible flavours (pH < 5.2)
  - “Clean silage” is important
Fatty acid composition

● The fatty acid distribution of milk will influence the texture of the cheese

➢ No influence on cheese quality when the milk contains more long chain unsaturated fatty acids (Allred et al., 2006; Lightfield et al., 1993)

➢ Cheese with reduced firmness when the milk contains more long chain unsaturated fatty acids (Jaros et al., 2001)
  • interesting aspect when dealing with low fat cheese.

➢ Fat reduced cheese made from milk produced by cows feed with red-clover (with a higher amount of long chain unsaturated fatty acids), had an improved texture (Svanborg, 2006).
What gives a good cheese milk?

- **Healthy animals**
  - Somatic cell count < 100 000/ml milk
  - High quality diet

- **High protein content**
  - BB variant of β-lactoglobulin and κ-Casein

- **Fresh (as short storage as possible)**
  - Low content of microorganisms < 10 000 cfu/ml milk
  - Low leakage of calcium-phosphate from the micelles
  - Low degradation of β-casein

- **Good flavour**
  - No off flavours

- **Good microbial quality**
  - Absence of pathogens
  - Absence of *Clostridium. tyrobutyricum*
  - Presence of good lactic acid bacteria
  - No antimicrobial agents