Why Some Cheeses are Sensitive to Food Safety Problems

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Wisconsin Center for Dairy Research

Center for Dairy Research “Solution Based Research Backed by Experience, Passion and Tradition”
Factors Influencing Enzyme or Microbiological Activity

• Temperature/time
• pH
• Acidity (And type: acetic, lactic, propionic)
• Ionic Strength (salt and mineral content)
• $a_w$ (water activity) and humidity
• Ability to compete in cheese environment
  – Oxygen, nutrient availability, competitiveness
• Initial numbers
Factors Influencing Enzyme and Microbiological Activity

- **Temperature**
  - More growth at higher temperature

- **pH**
  - Danger if high pH

- **Salt**
  - If high, slows ripening

- **Humidity**
  - If low, slows ripening
Factors Influencing Enzyme and Microbiological Activity: the BIG 3

Temperature and Time
• 38°F, 45°F, 50°F, 70°F

pH
• 4.4, 5.0, 5.4, 6.4, 6.7

Water Activity (aw)
• Mostly combination of salt, moisture, and acid content
### Water Activity of Various Cheeses

<table>
<thead>
<tr>
<th>Cheese</th>
<th>$a_w$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brie</td>
<td>0.980</td>
</tr>
<tr>
<td>Camembert</td>
<td>0.982</td>
</tr>
<tr>
<td>Cheddar</td>
<td>0.950</td>
</tr>
<tr>
<td>Cottage Cheese</td>
<td>0.988</td>
</tr>
<tr>
<td>Gouda</td>
<td>0.950</td>
</tr>
<tr>
<td>Gorgonzola</td>
<td>0.970</td>
</tr>
<tr>
<td>Parmesan</td>
<td>0.917</td>
</tr>
</tbody>
</table>

## aw Bacteria Growth Limits

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Growth Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>E. coli</td>
<td>0.96</td>
</tr>
<tr>
<td>C. botulinum</td>
<td>0.93*</td>
</tr>
<tr>
<td>L. monocytogenes</td>
<td>0.91</td>
</tr>
<tr>
<td>S. aureus</td>
<td>0.86</td>
</tr>
<tr>
<td>Yeast and Molds</td>
<td>0.65-0.70</td>
</tr>
</tbody>
</table>

*If other conditions are met, such as pH

Source: Food Research Institute, UW Madison
Classification of Cheeses by Type of Ripening

**Unripened cheeses**: made by coagulating milk proteins with acid

- **Acid + Rennet**
  - Fresh Mozzarella
  - Ricotta
  - Queso Blanco
  - Paneer
  - Mascarpone

- **Acid + Heat**
  - Cottage Cream
  - Neufchatel
  - Quark
  - Chevre

- **Acid Only**
  - Cheddar
  - Colby
  - Monterey Jack
  - Swiss
  - Edam/Gouda
  - Romano
  - Provolone
  - Mozzarella
  - Parmesan
  - Muenster
  - Brick

**Ripened cheeses**: made by coagulating with enzymes (rennet-type) and culture aids

- **Bacterial Ripened**
  - **Internal**
    - Trappist
    - Limburger
    - Liederkranz
    - Gruyere
    - Esrom
    - Comte
    - Port du Salut
    - Reblochon
    - Tilsit
  - **External**
    - Blue
    - Roquefort
    - Gorgonzola
    - Stilton
    - Danabaleu
    - Rosenbague
    - Bleu d’Auvergne
    - Blue Shropshire

- **Mold Ripened**
  - **Internal**
    - Camembert
    - Brie
    - Cambozola
    - Coulommiers
    - Saint Andre
  - **External**

Cheeses Beginning Life at a Very High pH

- Typically no starter culture added
- Cheese coagulated with rennet only
Fresh Latin American Cheeses

• Composition
  – High moisture (46%–58%) – tend to water-off
  – High pH (5.4–6.4)
  – Low or high salt (1.0%–3.0%)
  – Relatively low in fat (18%–25%)
• Commonly (but not strictly) non-melting
• No rind
• Micro issues due to high moisture and pH
Fresh Latin American Cheeses

- Para Frier
- Blanco
- Panela
- Fresco
- Ranchero
Fresh Mozzarella

• Composition
  – High moisture (65-68%) – packaged in slight brine solution
  – High pH (5.40-5.80)
  – Low salt (0.10-1.00%)
  – Relatively low in fat (17-19%)

• No rind

• Micro issues due to high moisture and pH
Ricotta

• Composition
  – High moisture (~77%)
  – High pH (~5.86)
  – Low salt (~0.50%)
  – Low fat (~8.5%)

• No rind

• Micro issues due to high moisture and pH if contaminated in package
Cheeses Beginning Life at a Low pH, but pH Rises Significantly During Ripening

• Smear Ripened Cheeses
• Blue Mold Cheeses
• White Mold Cheeses
Cheeses Beginning Life at a Low pH, but pH Rises Significantly During Ripening

Degradation of proteins (proteolysis) during ripening, which generates ammonia, neutralizes acid and raises the pH
Proteolysis

Peptides
Proteolysis: Breakdown of Casein

Connected aggregates (Farrell)

Disconnected + large peptides

Proteinase (coagulant)

Aldehydes, ketones, etc

NH₄ CO₂

Amino acids

NH₂N-C-C=O

Bacterial proteinases

Bacterial peptidases (amino peptidases)

Small peptides (bitter)
Decomposition Steps of Amino Acids During Ripening of Cheese

D. Hemme et al., Science des Aliments 2(1982)113
Consequences of Proteolysis

- Flavor
- Loss of stretch
- Increased melt and oiling-off (fat release during heating)
- Soft, pasty, smoother; shorter body in drier cheeses
- Increase in pH (release of ammonia)
Smeared Brick, Raclette, Gruyere, Limburger, and Havarti

- Cheese comes out of the brine, and is put into the smear room for 4-10 days at 60ºF and 95% RH
- Progression of Growth – surface smear
  - 1st Yeast
  - 2nd Micrococci
  - 3rd *Brevibacterium linens, Arthrobacter sp.*
Ripening Protocol for Soft Smear-Ripened Cheeses

• Put in cool room (~54ºF) overnight
  – pH ~4.9-5.4
• Brine (>18% salt) or dry salt
• Into smear room 7-10 days
  – 96-98% RH, 54-57ºF
  – Lower RH favors yeasts
    • Debaryomyces hansenii
  – Higher RH favors bacteria
    • Staphylococci, Micrococcus, Corynebacterium, Brevibacterium linens, Arthrobacter nicotianae
  – Finish with 85% RH to dry surface
  – Optional: wash off smear, then dry
• Package cheese in foil/storage 40-43ºF
• 45-55% moisture, pH surface >6.0
Smeared Brick, Raclette, Gruyere, Limburger, and Havarti

First—Yeast:

- Tolerates low pH and high salt concentration at cheese surface. Lactic acid is metabolized to $\text{H}_2\text{O}$ and $\text{CO}_2$
- Cheese pH starts at 4.8-5.2, then increases to 5.5 and even higher (6.5)
- Vitamins (panothenic acid, niacin, riboflavin, biotin) are synthesized, which are essential for the growth of *Brevibacterium linens*. Yeasts are also proteolytic and stimulate micrococci
Smeared Brick, Raclette, Gruyere, Limburger, and Havarti

Second—Micrococci Growth:

- *M. freundreichi*
- *M. caseolyticus*
- *M. varians*
- Very proteolytic, also forms alcohols, volatile fatty acids
Smeared Brick, Raclette, Gruyere, Limburger, and Havarti

Third—*Brevibacterium linens*, *B. casei*, *Arthrobacter sp.*:

- Reddish orange color to smear
- Very proteolytic, but can not grow below pH 5.5
- Produces H$_2$S (hydrogen sulfide), methyl mercaptan and ammonia (NH$_3$)
- Limburger is thin and this allows for ripening to occur throughout the cheese, resulting in a cheese with a creamy or almost liquid body
- Brick – flavor compounds diffuse into the cheese from the surface, enzymes do not
Limburger Ripening Room (Chalet)
Comte Ripening Cave (France)
Limburger Cheese

1 Day 5 Days 7-10 Days
Ripening or Curing Process

- **NH₄ Moves In**
- **Proteolysis by smear and molds produces ammonia**
- **Smear-Ripened or Mold-Ripened Cheeses**
- **Ca and Lactic acid move out**
- **Lactic Acid $\rightarrow$ CO₂ and Water**
- **Cheese pH increases from the outside to the inside (4.8 increases to >6.5)**
Mold Ripened Cheeses

• In order to ripen all the way through, mold needs oxygen to grow
• Mold spores are added to milk in blue-veined cheeses so cheeses are spiked (punctured)
• Brie and Camembert are sprayed with mold and ripen from the outside to the inside
Blue Cheese Ripening Caves
Blue Cheese Puncturing
Camembert

Traditional Camembert (mold ripened) *Penicillium candidum*

- Initially the cheese is low pH 4.8
- Body is brittle (now just the center)
- Ammonia leaches into cheese
- Causes pH to rise (6.5) and cheese becomes creamy
- Color changes from bright white to straw (whey)
Gradients in Camembert Cheese

Inner cheese mass = 8–14 mm; sub-rind = 0–6 mm and cheese rind = 1–3 mm

- (higher) Lactate concentration gradient (lower)
- (higher) Soluble Ca/PO₄ concentration gradient (lower)
- (higher) H⁺ concentration gradient (lower)
- (higher) Water gradient (lower)
- (lower) NH₄⁺ concentration gradient (higher)
- (lower) ASN and NPN concentration gradients (higher)

Cross-sectional view

Surface microflora enzymes

Lactate metabolised

Precipitation

High pH

NH₃ produced

SURFACE

Cheese surface
Proteolysis of White Mold Cheese
White Mold Cheese Ripening Rooms
“60-Day Aging Requirement Does Not Ensure Safety of Surface-Mold-Ripened Soft Cheeses Manufactured from Raw or Pasteurized Milk When \textit{Listeria monocytogenes} Is Introduced as a Post-processing Contaminant”

\textbf{Authors:} D'Amico, Dennis J.; Druart, Marc J.; Donnelly, Catherine W.
Thank You

Wisconsin Center for Dairy Research
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Center for Dairy Research “Solution Based Research Backed by Experience, Passion and Tradition”