Milk quality from Processors’ Perspective

Ranjan Sharma, PhD MBA
Processing of milk into value-added products & ingredients

- Raw Milk
  - Separation
  - Skim milk
  - Cream
  - Standardised milk

- **Skim Milk**
  - Skim Milk Powder
  - Membrane concentration
  - Evaporation & Drying

- **Cream**
  - Butter
  - Butteroil
  - Buttermilk
  - UHT Milk

- **Skim milk**
  - Market Cream
  - Market Milk
  - No-, Low-, Full-fat

- **Cream**
  - Whole Milk Powder
  - Ice Cream

- **Standardised milk**
  - Additives
  - Evaporation & Drying

- **Whey**
  - Whey Protein Concentrate
  - Membrane concentration

- **Casein**
  - Caseinate

- **Evaporation & Drying**

- **Processed Cheese**

- **Yogurt**

- **Infant Formula**
Sources of milk for processors

• Fresh milk
  – Own farm milk (raw)
  – Raw milk from another farmer
  – Pasteurised milk from another supplier

• Other dairy Ingredients
  – Cream (raw/pasteurored)
  – Skim concentrate
  – Skim/whole milk powder
Why quality of milk is important?

• Yogurt
  – Off-flavours/taints
  – Inhibition of the starter culture
  – Gel-strength
  – Syneresis
  – Ropiness/sliminess

• Cheese
  – Off-flavours/taints
  – Inhibition of the cheese starters
  – Affects rennet clotting time (RCT)
  – Cheese yield
  – Poor ripening
Why quality of milk is important?

• UHT Milk
  – Off-flavours/taints
  – Heat stability
  – Age-gelation/thickening

• WMP/SMP
  – Off-flavours/taints
  – Performance of the spray dryer
  – Functional properties
## Composition of milk of different animals

<table>
<thead>
<tr>
<th>Species</th>
<th>Total solids</th>
<th>Fat</th>
<th>Protein</th>
<th>Lactose</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Cow</td>
<td>12.7</td>
<td>3.7</td>
<td>3.4</td>
<td>4.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Goat</td>
<td>12.3</td>
<td>3.9</td>
<td>3.2</td>
<td>4.5</td>
<td>0.8</td>
</tr>
<tr>
<td>Camel</td>
<td>15.0</td>
<td>5.4</td>
<td>3.8</td>
<td>5.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Buffalo</td>
<td>16.8</td>
<td>7.4</td>
<td>3.8</td>
<td>4.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Sheep</td>
<td>19.3</td>
<td>7.4</td>
<td>4.5</td>
<td>4.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Yak</td>
<td>19.3</td>
<td>7.9</td>
<td>5.3</td>
<td>5.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Horse</td>
<td>11.2</td>
<td>1.9</td>
<td>2.5</td>
<td>6.2</td>
<td>0.5</td>
</tr>
<tr>
<td>Human</td>
<td>12.2</td>
<td>3.8</td>
<td>1.0</td>
<td>7.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Blue whale</td>
<td>55.0</td>
<td>40.9</td>
<td>11.9</td>
<td>1.3</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Source: Deeth, 2015
## Composition of milk of various breeds of cows

<table>
<thead>
<tr>
<th>Breed</th>
<th>Fat</th>
<th>Protein</th>
<th>Lactose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holstein/Friesian</td>
<td>3.5</td>
<td>3.1</td>
<td>4.9</td>
</tr>
<tr>
<td>Ayrshire</td>
<td>4.1</td>
<td>3.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Brown Swiss</td>
<td>4.0</td>
<td>3.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Guernsey</td>
<td>5.0</td>
<td>3.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Jersey</td>
<td>5.5</td>
<td>3.9</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Source: Deeth, 2015
Quality

• Quality is judged by a range of tests with varying degrees of objectivity, to ensure that a product
  • Is safe for human consumption with respect to both chemical or microbial contamination;
  • Conforms to food regulations such as those laid out by FSANZ, State or Council’s Health and Environment Office
  • Is capable of achieving a specified shelf life without spoilage;
  • Has as high an organoleptic standard as can be achieved within the existing constraints of manufacture, transport or distribution
Milk Quality

- Organoleptic/Sensory
- Microbiological
- Physico-chemical
- Nutritional
Bacterial aspects of pasteurisation

• Kills pathogenic bacteria (non-sporeformers)
• Kills most spoilage bacteria (non-sporeformers)
• Does **not** kill thermoduric bacteria, including sporeformers
  • thermodurics grow slowly at low temperature
  • pasteurised milk contains 1000 to 10,000 per mL thermodurics
• **Post-pasteurisation contamination is the major issue**
  • due to contamination from filling machine, air and packaging material
  • Post-pasteurisation contaminants are mostly psychrotrophs
    e.g. *Pseudomonas* – grow well at low temperature
• Shelf-life of pasteurised milk is 10-15 days
  • Much longer, if packaged aseptically
Spoilage of pasteurised milk

• Bacteria spoil milk through action of their enzymes on the milk components

• Off-flavours in spoiled pasteurised milk are:
  • Sour due to lactic acid
  • Bitter, putrid, sulfurous (due to protein breakdown)
  • Rancid due to breakdown of fat

• Skim milk spoils more quickly than whole (full fat) milk, mostly due to greater protein breakdown
Chemical aspects of pasteurisation

Inactivation of alkaline phosphatase (used as a test for pasteurisation)

Inactivation of milk lipase – otherwise all pasteurised homogenised milk would taste rancid

Small changes to proteins & water-soluble vitamins (e.g. vitamin C)

Little or no change to fats, lactose, minerals and fat-soluble vitamins (e.g. vitamin A)
Sensory/organoleptic quality

- Colour
- Odour
- Taste
- Foreign objects
Sensory quality – flavor defects in milk

• **Absorbed/Transmitted**
• **Bacterial/Microbial**
• **Chemical/Enzymatic/Processing**
  - A
    • Feedy, barny, cowy, weedy, unclean, lacks freshness, stale, refrigerator/cooler odors
  - B
    • Acid, bitter, malty, lacks freshness, unclean, fruity/fermented, putrid and rancid
  - C
    • Cowy (ketosis), salty, rancid, bitter, oxidized, sunlight, foreign, astringent, medicinal, flat, cooked
Microbiological quality

- Total viable count
- Thermoduric count
- Psychrotrophic count
Important Types of Bacteria in Raw Milk

Cause Spoilage
- Fermentative/acid producers (LAB - lactic acid bacteria; coliforms)
- Proteolytic, lypolytic, etc, (breakdown proteins, fats, etc.)
- Gas producers (coliform bacteria; some LAB)

Grow under refrigeration
- Psychrotolerant (e.g., Pseudomonas)

Survive pasteurization
- Thermoduric or thermo-tolerant
- includes spore-formers, some psychrotolerant species and strains

Cause mastitis infections in cows - Staphylococcus, Streptococcus, coliforms, others
Microbiological quality of raw milk

• Sources of bacteria in raw milk include:
  – Natural flora of healthy udder
  – Flora of mastitic cows
  – Exterior of cow
  – Dairy barn environment, air, water
  – Equipment milk contact surfaces

• Bacterial growth in raw milk influence by:
  – Milk residue on equipment
  – Prolonged milking time
  – Milk storage time/temperature
Microbiological quality of raw milk

Example of count:

- Good milk has 1,000-10,000 colony forming units (cfu)/mL
- Poor quality milk has > 100,000 cfu/mL
- Spoiled milk has >1000,000 cfu/mL

Source: Deeth, 2015
Effect of milk storage time on total count

Figure 1. Effect of milk storage time on total aerobic count. (●—●) Manufacturing grade milk, (○—○) grade A milk. Each data point is an average of nine observations.
Physico-chemical quality

- Inhibitors e.g. Antibiotics
- Storage temperature (°C)
- Milk solids
- Fat
- Protein
- Titratable acidity (％)
- pH
- Specific gravity
- Heat stability (Clot on boiling/alcohol stability)
Inhibitors

• Growth and acid production by starter cultures in yogurt and cheese may be inhibited by
  – Bacterial viruses
  – Bacteriophages
  – Antibiotics, sterilant/sanitiser and detergent residues
  – Free fatty acids produced by or as a result of the growth of microorganisms
  – Natural often called indigenous antimicrobial proteins.
Inhibitors

• Antibiotics
  – Mainly through mastitis treatment
• Natural antibiotic - Nisin
  – Some *L. lactis* naturally present produce nisin (a natural antibiotic) – normally not a problem
• Sterilant and detergent residues
  – (a) farm, (b) during transport to the factory and (c) the factory due to careless use of sterilants or detergents, incomplete draining or inadequate rinsing of equipment
• Free fatty acids
  – Through lipolysis – large concentrations are required for inhibition of LAB (e.g. >0.1% butyric acid)
• Natural antimicrobial proteins
  – The lactoperoxidase-thiocyanate-hydrogen peroxide (LP) system, Immunoglobins, Lysozyme, Lactoferrin, Vitamin binding proteins.

Antibiotics: Sensitivity of starter cultures to antibiotics

<table>
<thead>
<tr>
<th>Antibiotic</th>
<th>Lactococcus lactis subsp. cremoris</th>
<th>Lactococcus lactis</th>
<th>Mixed or multi-strain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Partial inhibition</td>
<td>Marked inhibition(3)</td>
<td>Partial inhibition</td>
</tr>
<tr>
<td>Penicillin*</td>
<td>0.05-0.13</td>
<td>0.21-0.3</td>
<td>0.09-0.15</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>0.11-0.16</td>
<td>0.3-0.4</td>
<td>0.09-0.21</td>
</tr>
<tr>
<td>Streptomycin</td>
<td>0.52-0.84</td>
<td>1.9-2.0</td>
<td>0.35-0.71</td>
</tr>
<tr>
<td>Erythromycin</td>
<td>-</td>
<td>2.0(1)</td>
<td>-</td>
</tr>
<tr>
<td>Chloramphenicol</td>
<td>-</td>
<td>5.0(1)</td>
<td>-</td>
</tr>
<tr>
<td>Chlortetracycline</td>
<td>0.015(1)</td>
<td>0.075(1)</td>
<td>-</td>
</tr>
<tr>
<td>Neomycin</td>
<td>-</td>
<td>5.0(1)</td>
<td>5.0(1)</td>
</tr>
<tr>
<td>Polymyxin B*</td>
<td>50(1)</td>
<td>300(1)(2)</td>
<td>300(2)</td>
</tr>
<tr>
<td>Ampicillin</td>
<td>-</td>
<td>2.0(1)</td>
<td>-</td>
</tr>
<tr>
<td>Novobiocin</td>
<td>-</td>
<td>5.0(1)</td>
<td>-</td>
</tr>
<tr>
<td>Cloxacillin</td>
<td>1.16-2.05</td>
<td>2.2-4.6</td>
<td>1.6-2.5</td>
</tr>
<tr>
<td>Bacitracin</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* Concentration expressed in International units ml⁻¹. Concentration of other antibiotics in mg ml⁻¹.(1) Determined using an agar diffusion method.(2) Markedly strain dependent.(3) Ranging from a reduction in acid production of 80% to complete cessation of acid production except for (1). Table taken from Haverbeck et al. (1983)

**Effect of milk storage temp on shelf life of raw milk**

<table>
<thead>
<tr>
<th></th>
<th>Milk storage time before coagulation on pasteurisation occurred</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5°C</td>
</tr>
<tr>
<td>Grade A Milk (Av 1300 cfu/ml)*</td>
<td>9</td>
</tr>
<tr>
<td>Manufacturing grade (&gt;106 cfu/ml)*</td>
<td>5</td>
</tr>
</tbody>
</table>

*Initial aerobic plate count

Hicks et al, 1986; [http://www.journalofdairyscience.org/article/S0022-0302%2886%2980452-0/abstract](http://www.journalofdairyscience.org/article/S0022-0302%2886%2980452-0/abstract)
# Quality analysis of milk

<table>
<thead>
<tr>
<th>Test</th>
<th>Reason</th>
<th>Method</th>
<th>Typical values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids</td>
<td>For standardisation&lt;br&gt;Gel strength – yogurt&lt;br&gt;Yield - cheese</td>
<td>Hydrometer&lt;br&gt;Oven drying</td>
<td>11-14%</td>
</tr>
<tr>
<td>Fat</td>
<td>Legal or sensory requirement</td>
<td>Gerber&lt;br&gt;Rose Gottlieb&lt;br&gt;Light scatter</td>
<td>3.0-3.5%</td>
</tr>
<tr>
<td>Protein</td>
<td>Fortification requirement for gel strength (yogurt)&lt;br&gt;Cheese yield</td>
<td>Infrared&lt;br&gt;Dye binding&lt;br&gt;Kjeldahl</td>
<td>3.0-3.5%</td>
</tr>
<tr>
<td>Antibiotics</td>
<td>Prevents starter growth</td>
<td>Delvotest P (DSM)&lt;br&gt;Lec-Tek</td>
<td>&lt;0.007IU per mL(&lt;0.004ug /mL)</td>
</tr>
<tr>
<td>Taints</td>
<td>Present chemical taints in cheese or yogurt</td>
<td>Odour/sniff test</td>
<td>Absent</td>
</tr>
</tbody>
</table>
## Quality analysis of milk

<table>
<thead>
<tr>
<th>Test</th>
<th>Reason</th>
<th>Method</th>
<th>Typical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clot on boiling (COB)</td>
<td>Assess poor quality milk/Heat stability</td>
<td>Boil in test tube</td>
<td>No clotting</td>
</tr>
<tr>
<td>Alcohol stability (better than COB test)</td>
<td>Assess poor quality milk/Heat stability</td>
<td>Mix milk:ethanol (1:1)</td>
<td>No precipitation</td>
</tr>
<tr>
<td>Somatic cell count</td>
<td>Detection of mastitis (white blood cells)</td>
<td>Various test kits</td>
<td>&lt;150,000/mL*</td>
</tr>
<tr>
<td>Titratable acidity</td>
<td>Growth of unwanted bacteria Souring of milk</td>
<td>Titration with NaOH till pink colour of the phenolphthalein endpoint</td>
<td>&lt;0.2% lactic acid</td>
</tr>
<tr>
<td>pH</td>
<td>Freshness of milk</td>
<td>pH meter</td>
<td>6.6-6.8</td>
</tr>
</tbody>
</table>

# Effect of milk on cheese quality

<table>
<thead>
<tr>
<th>Quality attribute</th>
<th>Cheese quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk from cows fed poor diet (low milk solids)</td>
<td>Lower cheese yield, softer &amp; high moisture curd</td>
</tr>
<tr>
<td>Milk from heat–stressed cow (low milk solids)</td>
<td>Low cheese yield, inferior cheese</td>
</tr>
<tr>
<td>Mastitis milk</td>
<td>Low cheese yield, increased RCT, reduced starter activity, poor cheese flavour and texture</td>
</tr>
<tr>
<td>Autumn/Spring milk</td>
<td>Autumn milk – high solids and cheese yield</td>
</tr>
<tr>
<td></td>
<td>Spring milk – low solids and low cheese yield</td>
</tr>
<tr>
<td>Late lactation milk</td>
<td>More yield due to high fat and protein in late lactation milk</td>
</tr>
<tr>
<td>Jersey/Holstein milk</td>
<td>Jersey milk has sorter RCT and firmer curd</td>
</tr>
<tr>
<td>Milk protein level</td>
<td>Milk with 0.1% more protein results in cheese yield by 0.13%</td>
</tr>
<tr>
<td>Casein content</td>
<td>More important than fat or whey protein – 0.1% reduction reduces cheese yield potential by 0.5%</td>
</tr>
</tbody>
</table>
# Effect of milk on cheese quality

<table>
<thead>
<tr>
<th>Quality attribute</th>
<th>Cheese quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>High fat – high moisture cheese</td>
</tr>
<tr>
<td>Casein/fat ratio</td>
<td>Complex relationship; ratio &gt;0.64 – enhanced cheese yield</td>
</tr>
<tr>
<td></td>
<td>High ratio – high coagulum strength</td>
</tr>
<tr>
<td>Casein/total protein ratio</td>
<td>Higher ratio – shorter RCT and firmer curd</td>
</tr>
<tr>
<td>Casein/WP ratio</td>
<td>Higher ratio – firmer curd with low moisture</td>
</tr>
<tr>
<td>Caseins</td>
<td>High K-casein - shorter RCT and more Syneresis</td>
</tr>
<tr>
<td></td>
<td>high B-casein - shorter RCT, firmer curd firmness and more Syneresis</td>
</tr>
<tr>
<td></td>
<td>high αS1-casein - shorter RCT and firmer curd</td>
</tr>
<tr>
<td>Casein micelle size</td>
<td>Small micelle - shorter RCT and tighter coagulum</td>
</tr>
<tr>
<td></td>
<td>Large micelle - softer curd</td>
</tr>
</tbody>
</table>

Effect of milk storage time on cheese moisture

Figure 4. Cheese moisture as affected by milk storage time. (●—●) Manufacturing grade milk, (○—○) grade A milk. Each data point is an average of nine observations.
Effect of milk storage time on cheese yield

![Graph showing the effect of milk storage time on cheese yield](http://www.journalofdairyscience.org/article/S0022-0302%2886%2980452-0/abstract)

Figure 5. Effect of milk storage time on yield of cheese solids. (●—●) Manufacturing grade milk, (○—○) grade A milk. Initial yield differences are due to different total solid concentrations in the milk. Each data point is an average of nine observations.
Effect of milk storage time on fat in cheese

Figure 6. Effect of milk storage time on percent fat in cheese. (●—●) Manufacturing grade milk, (○—○) grade A milk. Each data point is an average of nine observations.
Factors affecting quality of yogurt

- Raw materials
  - Raw milk, skim milk, cream, sugar, cultures, milk concentrate, milk powders, fruit/fruit conserves, stabilisers, flavours and colours
  - All can contribute micro-organisms and chemicals that affect the quality
  - Changes in the source and supply will cause variation in factors that can influence shelf life
  - Partnerships with approved suppliers and agreed specifications are recommended
Factors affecting quality of yogurt

- Raw materials – Milk
  - Variability in protein, lactose, fat and microbial flora
  - Variability in breeds of cattle, season and region
  - Milking & storage conditions the farm
- Raw materials – cream
  - Depends on the quality of milk used for separation
  - Methods of handling before and after pasteurisation
  - Susceptibility to lipolysis due to high fat (potential for rancid taste)
Summary - key quality criteria for milk

• Low natural microflora
• Free from inhibitors (antibiotics, sanitising chemicals etc)
• No contamination from mastitis milk and colostrums
• Free from rancidity
• Free from bacteriophages
• Free from hormones
• Stored below 5C
Acknowledgements

• Prof Hilton Deeth for a number of slides used in this presentation
Thank you!