Shelf-Life: Definition

“The period of time that a product can be kept under practical storage conditions and still retain acceptable quality.”

“The practical & safe storage life of a food.”

*A product can have “0” shelf-life if made from defective ingredients:

Rancid, Oxidized, Bacterial, Strong Feed, Unclean
- defects carry-over from raw milk -
Factors Influencing Milk Shelf Life

Raw Milk Quality
• Raw milk bacteriological quality:
  - total counts, specific types & metabolic activity
  - heat resistant or thermoduric psychrotrophs
• Somatic cells counts & herd health:
  - related proteases, lipases & other enzymes
• Absorbed, chemical or cow related flavor defects
  - feedy, barny, lipid oxidized, rancid, medicinal

Processing & Post-Processing Defects
• Post-Processing Contamination (Gram neg./Gram pos.)
• Thermoduric psychrotrophs (Gram pos.)
• Process/Handling defects (e.g. cooked, light induces flavors)

Raw Milk Quality - Influence on Shelf Life

Flavor Defects - Non-Microbial

Foreign or Chemical:
• Flavor/odor depends on contaminant
  - sanitizers, ointments, oils,
  exhaust fumes
• Chlorophenols – medicinal/ “bandage-like”
  - phenols; sanitizers, pesticides, tannins (water)
  - chlorine/iodine; sanitizers, cleaning chemicals
• Cowy/Ketosis (chemical/biochemical):
  - unclean, medicinal (acetone)
• Other defects perceived as “chemical”
  - light induced; lipid oxidation
Feed or Barn Related Flavors:

- Transmitted (absorbed):
  - lungs/rumen $\rightarrow$ blood $\rightarrow$ milk

- Flavor/odor notes of certain feeds
  - hay, silage; generally not objectionable

- Stronger/poor quality feeds
  - moldy feeds, apple pumice
  - onion/garlic, bitter weeds

- Barny/unclean from poor ventilation
  - manure/urine odors

Rancid (free fatty acids from fat lipolysis):

- Baby vomit, provolone cheese
  - over-agitation, starved pumps, air leaks,
  - homog. raw milk/mixing raw/homog.
  - influenced by equipment design
  - influenced by herd health

Oxidized (auto-oxidation of unsat. fatty acids):

- Wet cardboard, old-oil, tallow, greasy mouth-feel
  - catalyzed by divalent cations - (copper, iron)
  - spontaneous related to feed or cow
    - high fat feeds (e.g., soy beans)
    - lack of anti-oxidants (e.g., vitamin E)
Raw Milk Quality - Influence on Shelf Life

**Bacteriological Quality**

**Farm Sources**
- Natural flora of the healthy udder (very low)
- Flora of mastitic cows (low to high)
  - Exterior of the cow (low to medium)
  - Dairy barn environment, air, *water* (low)
  - Equipment milk contact surfaces (low to high)

Increases due to bacterial growth:
- Milk residues on equipment
- Prolonged milking times
- Milk storage time/temperature

Note: *Bacterial types vary with source and conditions*

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**Total Bacteria Count Standards For Raw Milk (USA)**

- Producer Raw Milk (PMO*): $\leq 100,000/ml$
- Commingled Raw Milk (PMO*): $\leq 300,000/ml$
- Industry Processing Standards: $< 50,000/ml$
- Industry Premium Standards: $< 10,000/ml$

Milk can be stored for an additional 72 hours at the plant = potential for further growth (dependent on types, #s, temperature)

PMO = Grade “A” Pasteurized Milk Ordinance
Raw Milk Quality - Influence on Shelf Life
Bacteriological Quality

Raw Milk Time Line

**Farm:**
Milk Picked-Up Every 48 Hours
100,000 cfu/ml limit

**Transport:**
To Dairy Plant in ___ Hrs
300,000 cfu/ml limit

**Plant Storage:**
Tanks Washed Every 72 Hrs
300,000 cfu/ml limit

How are bacterial numbers influenced during time line?

Factors:
- Initial Load
- Types
- Temperature
- Growth Rates

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Raw Milk Quality - Influence on Shelf Life
Bacteriological Quality

**Total bacterial counts at the time of processing:**
- Defective raw milk will give defective processed milk
- Limited info when raw milk is “acceptable”
  - reports of >10⁶ in raw before defects are apparent in pasteurized milk up to 14 d

**Types & metabolic activity:**
- Bacteria differ in spoilage capabilities/enzymes
- Heat resistant enzymes from select organisms (?)
  - most published work on *Pseudomonas* spp.
  - most influence on UHT shelf-stable products
  - limited information on pasteurized milk
- Heat resistant psychrotrophic bacteria (e.g., spore formers)
Raw Milk Quality - Influence on Shelf Life
Bacteriological Quality

Total bacterial counts at the time of processing:
- Defective raw milk will give defective processed milk

• Acid/Sour/Coagulated:
  - growth of lactic acid bacteria to large numbers;
    \textit{Lactococcus lactis} most common
  - often associated with poor cooling (esp >70°F)
  - dirty equip/poor hygiene may be promoting factor

• Malty:
  - malt, caramel, “grape-nut” like odor /flavor
  - \textit{Lactococcus lactis var maltigenes}

### Raw Milk Quality - Influence on Shelf Life
Bacteriological Quality

<table>
<thead>
<tr>
<th>ID</th>
<th>Raw Milk SPC/ml</th>
<th>Days@7°C</th>
<th>Pasteurized SPC/ml</th>
<th>Flavor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16,000,000</td>
<td>7</td>
<td>400</td>
<td>Slight bitter</td>
</tr>
<tr>
<td>2</td>
<td>27,000,000</td>
<td>7</td>
<td>100</td>
<td>Very bitter</td>
</tr>
<tr>
<td>3</td>
<td>11,000,000</td>
<td>7</td>
<td>200</td>
<td>Good</td>
</tr>
<tr>
<td>4</td>
<td>5,000,000</td>
<td>7</td>
<td>1,500</td>
<td>Good</td>
</tr>
</tbody>
</table>

Raw Milk Quality - Influence on Shelf Life
Bacteriological Quality

Heat Resistant Enzymes:
- Little published work on pasteurized and ultra-pasteurized milk
  “Defects in pasteurized milk caused by these enzymes have not been described. It is likely that the period of storage is too short to produce noticeable off-flavors.”
  “Leloup et al found that bacterial proteases may influence milk flavor during prolonged storage of pasteurized milk, provided recontamination level is low.”

- Opinion: Significant defects in pasteurized & UP milks unlikely when raw milk counts at processing are < 300,000 cfu/ml …in most cases …

News Flash:
Shelf-Life expectations are getting longer

Raw Milk Quality - Influence on Shelf Life
Heat Resistant Enzymes

Testing for Heat Resistant Enzymes:
- No “Practical” Commercial Tests
- Tests researched:
  - Enzyme/substrate methods
  - ELISA based methods

Testing for the “Potential” for Heat Resistant Enzymes:
- Total bacteria counts at the time of processing DMC, SPC, BactoScan
- Selective Gram-Negative counts
- Proteolytic counts
Microorganisms that Survive Pasteurization

High Survival Rate:  
- *Microbacterium lacticum*
- *Micrococcus* spp.
- Spore-formers (in spore phase) *Bacillus*
- *Paenibacillus*
- *Clostridia*

Lower Survival Rate:  
- *Enterococcus* spp.
- *Lactobacillus* spp.
- *Streptococcus* spp.

Equipment Films, Cracks & Crevices

Soil, Feeds, Manure = Soiled Teats, (Equipment)

Sources of Thermotolerant Bacteria  
(numbers > 20,000 in raw = illegal pasteurized milk)

Dairy Farms:  
- areas of persistent poor cleaning, old rubber parts, poor cooling, dirty cows & environment

Bulk Milk Tankers:  
- poorly cleaned tanks, bridges, milk hoses

Plants:  
- separators/clarifiers, poorly cleaned raw tanks

Often used as an indicator of poor hygiene on the raw side  
(Thermotolerant Counts: heat milk 63°C/30 min before SPC)
Raw Milk Quality - Influence on Shelf Life
Testing Procedures

Best indicator of raw milk’s influence on shelf-Life
is it’s quality at the time of processing.

- **Standard Plate Count:**
  Plate on SPC agar, incubate 32°C/48 hr
  Provides only historical data
- **Direct Microscopic Counts:**
  Can be used for bacteria and somatic cells
- **Sensory Evaluation:**
  Odor and appearance of milk
  Tasting raw milk not advisable
  - some “lab pasteurize” & taste

Best indicator of raw milk’s influence on shelf-Life is it’s quality at the time of processing.

**Raw Milk Bacterial Tests:**

- **Laboratory Pasteurization Count:**
  Lab pasteurize milk 63°C (145°F)/30 min
  Perform SPC (32°C/48 hr) on heated milk
  *Alternative: Psychrotroph Count 7°C/10 d*

- **Preliminary Incubation Count (Raw):**
  Incubate milk at 12.8°C (55°F) for 18 hr
  Perform a SPC compare to fresh raw SPC

- **Coliform Bacteria Count:**
  Plate milks on Violet red Bile Agar

*These tests are used as indicators of poor production methods on farm. No direct relationship to processed milk shelf-life has been found in the literature.*
Raw Milk Quality - Influence on Shelf Life

Relationship of Raw Milk Bacterial Tests to Shelf-Life

- **Laboratory Pasteurization Count:**
  - Detects bacteria that survive lab pasteurization
  - Does not determine whether these organisms are psychrotrophic unless *Psychrotroph Count 7°C (45°F)/10 d* performed
  - Psychrotrophic Spore Count assay may be more useful**

- **Preliminary Incubation Count (Raw):**
  - Detects bacteria that grow well at 55°F, most are Gram-negative (?)
  - Gram-negative bacteria do not survive pasteurization
  - Does not indicate levels of heat resistant enzymes

- **Coliform Bacteria Count:**
  - Coliform Bacteria do not survive pasteurization

Factors Influencing Shelf Life of Fluid Milk

**GN Post-Processing Contamination**

- Most psychrotrophic bacteria associated with reduced shelf-life are Gram-negative rods (*Pseudomonas spp.*)

- Generally do not survive pasteurization, occur as post-processing contaminants (i.e. dirty equipment, *Indicators* of post-pasteurization contamination)

- Very low levels of contamination can result in reduced shelf-life of fresh dairy products
Factors Influencing Shelf Life of Fluid Milk

Sources of Thermoduric Psychrotrophs:

Raw Milk
- soil, grass, silage, concentrates, manure
- cows, milking equipment, bulk tank
- transport tankers, hoses
- tanker CIP systems (?)
- plant storage & handling

Processing:
- HTST/separator
- filling machine
- packaging material

Sources of Bacteria in Raw Milk

Pre-Milking Hygiene & Milk Let Down Recommendations

- Minimize water use
- Focus attention on teat surfaces, not udders
- Use an approved sanitizer (i.e. predip, spray)
- Assure complete coverage & contact time (> 30 sec)
- Provide 10-20 sec let-down stimulus
e.g. teat message, fore stripping, teat drying
- Remove all dirt from teat surfaces
e.g. wipe thoroughly dry & clean
  with clean towel

Available at … http://www.nmconline.org/articles/prepping.pdf
Sources of Bacteria in Raw Milk

Influence of Pre-Milking Hygiene on Milk Bacteria Counts

<table>
<thead>
<tr>
<th>Teat Treatment</th>
<th>Total Count</th>
<th>Coliform Count</th>
<th>Anaerobic Spores</th>
</tr>
</thead>
<tbody>
<tr>
<td>No treatment</td>
<td>7,500</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>Water wash, wet</td>
<td>7,900</td>
<td>31</td>
<td>1.3</td>
</tr>
<tr>
<td>Water wash, dry</td>
<td>4,200</td>
<td>16</td>
<td>0.5</td>
</tr>
<tr>
<td>NaOCl wash, wet</td>
<td>4,100</td>
<td>38</td>
<td>0.7</td>
</tr>
<tr>
<td>NaOCl wash, dry</td>
<td>1,500</td>
<td>14</td>
<td>0.003</td>
</tr>
</tbody>
</table>

1 gram of teat soil of 100,000,000/gr into 30 lbs of milk = 7000/ml

Counts as high as 100,000/ml of milk have been associated with dirty cows.

1 From Bramley and McKinnon. 1990. The Microbiology of Raw Milk in Dairy Microbiology.
2 Counts per ml of milk. Mean of 30 trials for each treatment. Spores are related to cheese defect.
3 From J. Sumner. IDF Symposium Proceedings. 1996

Milk Under the Microscope

*Staphylococcus aureus* associated with poor refrigeration

*Lactococcus* species associated with poor refrigeration

*Streptococcus agalactiae*
Raw Milk Quality - Influence on Shelf Life
Somatic Cell Counts

Legal Limits for Somatic Cells:
- USA 750,000 cells/ml
- Canada 500,000 cells/ml
- EU 400,000 cells/ml

Herd Health Concerns:
> 2-300,000 cells/ml

Quality Concerns:
- proteases (e.g. plasmin), lipases
  - off-flavors in cheese and milk
  - reduced yields and texture defects in cheese

Summary How Raw Milk Bacteria Influence Product Quality

- **SPC of Producer Samples**
  - most often does not milk at processing
  - depends on the types present, growth during storage

- **SPC at the time of Processing**
  - best indicator of product quality potential
  - counts >1 million suggest damaged, defective raw
  - counts > 300,000 may heat stabile enzymes

- Most bacteria in raw milk do not survive pasteurization
  - extended refrigeration selects for Gram-negatives

- **SPC of fresh pasteurized milk mostly thermodurics (LPC)**
  - limited growth of thermodurics in refrigerated raw